DOCUMENT RESUME

ED 305 426 CE 050 678

AUTHOR Fellenz, Robert A., Ed.
TITLE Cognition and the Adult Learner.
INSTITUTION Montana State Univ., Bozeman. Center for Adult Learning Research.
SPONS AGENCY Kellogg Foundation, Battle Creek, Mich.
PUB DATE May 88
NOTE 70p.; Selected papers presented at the meeting of a summer Institute on Adult Cognition (Bozeman, Montana, 1987).
PUB TYPE Collected Works - General (020) -- Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Adult Basic Education; Adult Education; *Adult Learning; Adult Students; *Biology; *Cognitive Processes; Educational Technology; *Epistemology; High School Equivalency Programs; Postsecondary Education; *Problem Solving; Research and Development; Research Methodology; Research Needs; *Theory Practice Relationship

ABSTRACT

This report contains six research papers and a summary of a panel discussion on the topic of cognition and the adult learner. The papers are as follows: "Psychology and Adult Cognition" (Wilbert J. McKeachie); "Biology and Adult Cognition" (Frank Farley); "Technology and Adult Cognition" (Barbara Grabowski); "Enhancing Cognitive Skills" (Richard A. Block); "How We Solve Problems" (Charles E. Moon); and "From Research to Practice: The Practitioner's Perspective" (Joanne Erickson). The panel discussion focused on "Doing Research in Adult Learning." (KC)

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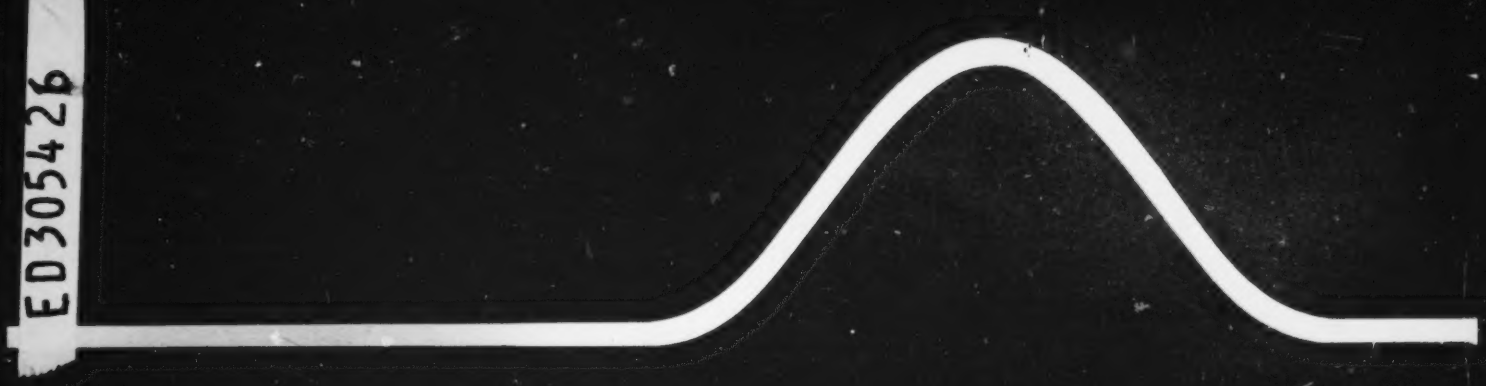

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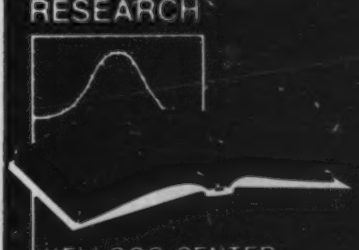

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COGNITION AND THE ADULT LEARNER

Papers from an Institute Sponsored by
The Center for Adult Learning Research
Montana State University
Bozeman, Montana

Funded by
The W. K. Kellogg Foundation

Editor
Robert A. Fellenz

May 1988
Center For Adult Learning Research
Montana State University
Bozeman, Montana

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PREFACE

Shortly before his death J. Roby Kidd stated in *Library Trends* (Spring, 1983) that he had come to an exciting realization: the focus had changed from adult *education* to adult *learning*. This he saw as such a tremendous transformation that he struggled for words to describe it--calling it "a paradigm shift," a "perspective transformation," "a leap in consciousness" (p. 527). It is to this shift of attention to adult learning and to prophets, such as Kidd, who expounded on the value of attending to adult learning research that this monograph is dedicated.

The articles in this publication are the result of an Institute on Adult Cognition held at Montana State University during the summer of 1987. The institute was sponsored by the Kellogg Center for Adult Learning Research which had been established at the University through a grant from the W. K. Kellogg foundation. In line with the mission of the Center to stimulate research in adult learning, a small group of professors of adult education were invited to meet with several national leaders in cognitive psychology. The hope was that the insights of the experts in cognition would be infused into relevant research and theory development by the adult education professors.

McKeachie's opening presentation overviewed a decade or more of development in cognitive psychology. Key concepts, such as levels of attention, clumping and visualizing as memory aids, the relation of automatization and elaboration to retention, and the vital role of motivation in all learning were described. But McKeachie also mapped out potentially rich sources for adult education research insisting that researchers in adult education should focus on the student and delve into such areas as the effect of previous knowledge on learning and the strategies used by adult learners in noncaptive settings.

Farley's comments were future oriented in that he addressed recent findings in brain research and postulated various biological bases for the examination of learning. He integrated much of his recent thought into a stimulating description of the "Type T Personality" which he then applied to many educational situations. Farley, too, constantly reminded the adult educators present of the impact of motivation on learning and the need to learn more about it.

Grabowski summarized the major principles to be cognizant of when examining the effect of technology on adult learning. She tied such research to recent developments in cognitive psychology by showing how the internal processing of information received through media is receiving major attention by researchers. Grabowski joined Farley and McKeachie as a panel responding to questions of the adult educators regarding the implemetation of adult learning research.

Collaborative efforts are often called for in adult learning research. In an attempt to model some practical approaches to collaboration on learning research, Charles Moon and Richard Block, professors at regional universities, and Joanne Erickson, a Montana practitioner, were also invited to share their research ideas with the group. Block's paper demonstrates a psychologist's approach to a question of interest to many adult educators, i.e., helping others learn how to learn. Moon gave numerous examples of collaboration between cognitive psychology and adult education in doctoral dissertation work. Erickson's presentation stimulated thought regarding the variety of opportunities that do exist for practitioners and researchers to work together.

These papers have been included in this monograph both for the insights they contain and the potential for collaboration they exemplify.

Kidd's observation that adult education is moving from an emphasis on education to a focus on learning is most timely. The "black box" of the behavioral school has been pried open by the cognitive psychologists, and that very process has unearthed exciting challenges for research in adult learning. At the same time biology, sociology, and technology are suggesting mind boggling scenarios for tomorrow's educators that call for much deeper insights into how adults learn. It is the hope of the Kellogg Center for Adult Learning Research that monographs such as this will contribute to conceptual development and research on adult learning.

Robert A. Fellenz
Montana State University

ACKNOWLEDGEMENTS

The funding for the Institute on Adult Cognition and the publication of this monograph was provided through a grant from the W. K. Kellogg Foundation. The long-standing support of this foundation for continuing adult education and for inquiry into issues relevant to lifelong learning is broadly recognized.

Special appreciation is also due to the presenters of the papers. All were most gracious in reviewing transcripts of their presentations and turning their verbal messages into documents more easily read. But even more appreciated is the time and effort they gave to applying their insights to the cause of adult learning research and to their stimulating interaction with institute participants.

Staff members of the Kellogg Center for Adult Learning Research contributed much time and effort to this publication. Joyce Clark not only directed the typing of the manuscripts but kept the whole production process moving. Randy Knuth, with his insight into computers and desktop publishing, made the words appear on paper so neatly and orderly. Gloria Gregg, project coordinator, directed cover design and production efforts. Kellogg doctoral fellows, Rodney Fulton, Barbara Storm, and Betty White did much proofing of manuscripts.

Finally, acknowledgement is due to the participants of the summer institute, especially the professors of adult education who came to sit on a distant mountain top to contemplate promotion of adult learning research. Rosemary Caffarella, Ron Cervero, Chere Coggins, Michael Day, David Gueulette, Lloyd Korhonen, Helen Lewis, Larry Martin, Sharan Merriam, Dan Pratt, and Burt Sisco shared, questioned, and supported all involved. Their continued support of the Center for Adult Learning Research is appreciated. Gary Conti and Ralph Brockett together with former Kellogg fellows Barbara White, Connie Blackwood, Patricia Lundgren, and John Rogers, were the supporting cast who assisted in carrying out this fascinating investigation into adult learning research.

Editor

PSYCHOLOGY AND ADULT COGNITION

Wilbert J. McKeachie

My task is to present a brief summary of cognitive psychology. This is not as difficult as it may appear to be. To some extent what psychologists have come to in the last 20 years--the field that's called cognitive psychology--is not as remote from every day thinking about learning and thinking as the behavioristic theory which preceded cognitive psychology. For example, if I asked you why you came here today, you would probably say something like, "Well, I thought that maybe I could learn something from it. I decided that this might be more important to me than spending the day playing tennis or hiking or doing something else." You can see that in describing why you act the way you do, you are using terms like "I thought" or "I think" or "I decided I'd learn." These are terms that imply that something is going on inside your head. This is the way people have for years thought about why people behave the way they do.

So why did psychology ever get away from this common sense view? In the early part of this century psychologists felt that they could not become scientific unless psychologists focused on those things that were observable and replicable variables that could be pinned down and measured very precisely, just as chemists measured various aspects of the chemical elements and chemical compounds. When I was a graduate student in 1945-48, "mind" was a dirty word in the language of psychology because things that were in the mind were unobservable. Hence, the feeling was that thought could not really be part of a science of the sort that psychologists were trying to build. During the period from 1912 to 1960 or thereabouts, the dominant way of studying psychological phenomena was to measure behavior in situations that were very well controlled. You could repeat an experiment; you could report it in the literature; somebody else could do it; and you could see whether they got the same results. The attempt was to make these situations simpler and simpler so that you could be very sure exactly what was happening.

When I started as a graduate student, psychologists had already decided that human beings had too much past experience and too many different kinds of things happening to be good organisms to study. Research was largely done with white rats. In the Natural Science Building at Michigan we had a room which had been designed by Professor Shepard, the Chairman, just for a rat maze. Graduate students could lie on the floor on the room above and look down at this enormous maze with all of these blind alleys. About the time that I was a graduate student, psychologists decided that such mazes were too complicated. So the mazes became straight T-mazes in which the rat only had to decide whether to turn left or right. I used "decide"; the behaviorist would have thought that the rat didn't decide. It learned to turn right or left depending on where the food was and built up habit strength by the reinforcement of the food.

While I was still a graduate student some people said, "That's still too complex. We will have to measure how fast they can go down a maze to get to the end of it and

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Wilbert McKeachie is the Director of the University of Michigan's National Center for Research to Improve Postsecondary Teaching and Learning and Professor of Psychology and Education at that institution.

that will be even more precise." Well, as you can see, that had great advantages in terms of precision, and objectivity. We learned a good deal during the period when behaviorism was dominant. Progress was made in establishing certain variables that made a difference for behavior, at least rats' behavior. Sometimes there was difficulty in extrapolating these results from the rats, to the human being. B. F. Skinner, who is probably our most prominent living behaviorist, actually wrote books about how we could revolutionize learning in schools if we would just apply these principles that had been learned from rats.

In the early 1960's there was a big flurry of book companies and high-tech companies such as Xerox and Raytheon getting into the manufacture of teaching machines that were to teach in ways that were much more efficient than simple naive human beings could teach because they were going to embody the principles of learning that Skinner had discovered. It turned out that teaching machines could teach, but not as well as human beings. In the first place, people got bored. Machines turned out to be useful for some things, but in general the dreams of great wealth that the first teaching machine creators had in mind never came true.

Now, what was wrong? Well, the behaviorists' notions of why we act the way we do were based upon looking at experiences people had in the past, saying that whatever you do at this moment in time is a function of what has happened to you in the past. And that's a logical type of assumption to make. In everyday life we often explain behavior in terms of past experiences, our childhood training, our lack of opportunity. The behaviorists' notion was that the reason you decided to come here today is a function of past experiences in coming to conferences and listening to lectures and reinforcement as a result of those experiences. The "Reinforcement" means essentially that things that happened that were pleasant or rewarding strengthened the tendency of the same behavior to happen again.

To a large extent that theory works pretty well; that is, people do tend to repeat things that have been rewarding. But when you start looking at behavior of real human beings, and even of animals, you find out that this law of learning and the principles that Skinner and his predecessor, Thorndike, had developed did not work in every situation. For example, Eelen and d'Ydewalle at the University of Leuven in Belgium showed that if you rewarded a rat for turning right, the next time the rat would turn left. There was a tendency not to repeat things that were rewarded on the next trial. This seemed to be contrary to the rules of behavior as we knew them at that time.

Harry Harlow at the University of Wisconsin studied monkeys and their problem solving. Harlow found that if you gave monkeys puzzles to solve, (e.g. little wire puzzles where you are supposed to manipulate the wires until you can pull the parts apart), they love to do this. If Harlow rewarded them every time they solved a puzzle and then stopped giving a reward, the monkeys wouldn't do the puzzles anymore. But if Harlow did not give them rewards, they kept on solving puzzles. That seemed to be contrary to the notion that rewards strengthened behavior.

During the period of changing views, one of our students was a New Zealand physical educator or kinesiologist, David Russell, who is now head of the school of kinesiology at Otago University. In his doctoral dissertation, Russell did something that seemed to be contrary to behavioristic principles. One of the principles of behavior is: if you practice something and you're given feedback about whether you've made the right or wrong answer, you will learn that practiced response. It is not just practice alone that makes perfect; it is practice plus feedback that makes perfect. In general, something you've practiced and been given feedback

about the correct response should be better than something that hasn't been practiced. That just seems to be common sense as well as behaviorist theory. If you don't practice a response how can you learn it? What Russell did was to compare two groups on a task. Seated in the dark, the subject's task was to move a pencil to hit a dot of light 16 cm from the starting point. This is a simple motor skill. Half of his subjects practiced that movement; i.e. they started at the required point and practiced the required movement. The other half of his subjects never practiced that task, but they practiced from other points 16 cm from the target. When he compared the performance of the two groups after their practice the group who had never practiced the task did just as well as those who had practiced it. This, of course, seems not to fit with conventional notions of behaviorism. It does fit, however, with the notion that even in motor skills we are building up in our minds some kind of schema, a mental map or picture of the way things are. It is that mental map which guides our behavior rather than just a specific mental response. A schema is an organized set of concepts or an organized set of movements; it is something in the head. So, psychology in the last 25-30 years has moved away from behaviorism, in the sense that we now talk about things that are inside the head. We call this cognitive psychology. It is now legitimate to talk about mind, about intentions, about thoughts, about feelings.

So what is cognitive psychology? Well, cognitive psychology is how we get organized and store information--how we make sense out of our experiences, and then remember and use our past experience to guide our behavior. Cognitive psychologists are still behaviorists in the sense that their ultimate criterion is still behavior and their theories are tested against behavior. Ultimately the difference is that now, in trying to be precise about how behavior is determined, we're talking about things going on inside the brain, inside the head. (You'll hear more about the brain probably from Frank Farley in his talk.) The new psychology is like everyday psychology, our ordinary thinking, in that we are using terms like "think," "decide," "solve problems," "feel," and so forth. The difference between psychology as it is today and the kind of everyday psychology that people have used for centuries is that psychologists now have quite precise methods of measuring some of the things that are going on in the mind. It's not that they are sticking electrodes in the head and measuring them, (although they are doing that too), but we have methods for measuring what is going on in the mind. An example is the use of reaction time methods. A person is given tasks which, according to our theory, involve different steps or different cognitive activities (different things going on in the head). The experimenter then measures whether or not there are two steps or one step by measuring very precisely in milliseconds the time that it takes to respond. In summary, part of the reason that cognitive psychology came into play was that behaviorism was not working for some things. There were some things that could not be well explained.

A second reason was that new methods were developed that were more precise for studying short-term memory and other mental processes in ways that could be repeated and were observable.

Probably a third reason we switched from behaviorism was people just got bored with running rats. It was just more interesting to work with human beings and to work with meaningful material than with things that were not very meaningful and really did not make much difference to anybody. The behaviorists (e.g. Hullian theory) got more and more technical and less and less interesting because they seemed so far removed from the real world.

Cognitive psychology is doing that too.

There are very technical, very intricate theories of cognition. In perception we can debate set theory, prototype theory, feature similarity theory, and other theories of how a thing is recognized. There are various theories which have slightly different ways of accounting for and explaining learning and memory. We have elaboration theory and depth of processing theory and so forth. There are still many theoretical controversies and I am not going to take you into these. They are interesting, but I'll try to give you what I see as some of the dominant notions that might make a difference for education. As I said this is not going to be greatly different from the way you now think about thinking, but our hope is that cognitive psychology will give you some different ways of thinking that will be stimulating to you and heuristic in thinking about kinds of research you might do. This is not "TRUTH" in some kind of absolute form; it's a way of looking at how people think and why they behave the way they do. There will be other ways 10-20 years from now that presumably will build on this kind of theory just as this builds on some of the things that were learned in behaviorism. But this is where we are right now, and for me it's a fascinating area.

Let's look at some of the key problems that cognitive psychologists are concerned about. One of the first is attention. If students are going to learn, they typically have to be paying attention. That does not mean that you do not learn things that you're not paying attention to. You could probably tell me where the doors are in this room even though you may not have paid very much attention to them. So there is learning without conscious attention, but generally speaking you are going to learn more if you try to pay attention to me than if you are doing something else and my voice is just the background. When I was a graduate student, we had the notion that you could pay attention to only one thing at a time. I remember that we were concerned about the problem, "How does an organist handle the complexity of playing an organ?" The organist has to keep both feet and hands going, read the music, think about how to phrase the music and work out how to interpret it. It seemed from our theories of that period that to play an organ was beyond the human capacity of attention, and yet organists did it. Our theory was that they switched attention. At first they paid attention to their hands and then to their music and then to their feet and so forth. They were switching back and forth very, very rapidly. This was not a very satisfactory theory; so let's see whether current theory is likely to do better.

Our theory now is that attention is not like a search light that focuses in on one area and leaves everything else in darkness, but that attention is a capacity in which certain things are in focus. These are the primary things that you are paying attention to. Right now I would hope that that is my voice and face; that you're paying attention to me. I should say that one can separate visual, auditory attention, but one of the reasons why people should not sit in the back of a hall is that auditory attention is pretty well driven by visual attention. If you can't see me very well, you're probably not going to listen as well either. In fact, there's some evidence that if you can see my lips move you will get more--not just because you are lip reading but because that is another way of focusing your attention on what I'm saying. So, a primary task is listening to me, making sense out of what I'm saying. At the same time some of you at least are trying out a secondary task, taking notes. Presumably you're taking notes at the same time that you're listening, so you've got two things going on at once. Just as Barbara, who drove us here, was talking while she was driving . . . .two activities. If both of these tasks are relatively easy tasks for you, there might also be some spare capacity that you are not even using.

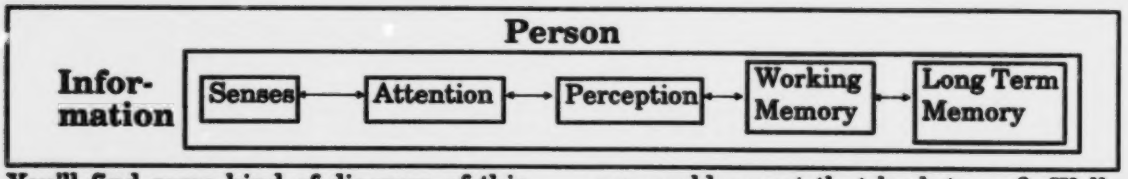
In most situations there might also be a certain amount of attentional capacity that is used just to keep track of dangers in the environment, so that if there's a loud noise or an earthquake or something, we're going to respond. Presumably we evolved in a time when we had to worry about attacks by other human beings or by wild beasts or by falling trees so that we're constructed in a way that leaves a certain amount of our capacity available to pick up signals that might lead to danger. This is an example of what cognitive psychologists are concerned about. One of the key things is this notion of primary tasks, secondary tasks, spare capacity, and surveillance as sharing attentional capacity.

When I speak to an audience that is primarily second language English speaking, I'm aware that I have to speak more slowly because they are going to have trouble keeping track of my English vocabulary. It is going to be more difficult for them, and it is going to take more of their capacity to understand my language. When I tackle a new topic in psychology, I try to put in more repetition and I try to speak a little more slowly because it is more like a second language for the students. Some of the things that are commonplace to me are not commonplace to them. If I speak to freshmen I use a different vocabulary than I would if I were speaking to a group of graduate students and I try to present ideas more simply and put in more redundancy.

Because the task of note taking, which I encourage my students to do (and I'll tell you later why note taking is a good technique), takes capacity as well, while they're taking notes on difficult, new, material they're not able, at the same time, to hear what the lecturer is saying. There's evidence from studies by Jim Hartley, an English psychologist, as well as from studies in this country, that students who are less competent or have less background, should take fewer notes rather than more notes. So we have this paradoxical situation that in general the more difficult the material, the fewer notes you should take; otherwise you're going to miss a lot of the lecture.

There is also the problem of spare capacity. Let's suppose that we have a primary task that doesn't take very much capacity and a secondary task that also is well learned. You've got a lot of spare capacity left. One of the characteristics of attention is that when the situation is too easy, not demanding enough, that spare capacity tends to draw you off into daydreaming or other kinds of activities. That leads to the converse of what I just said about note taking. If it's a very easy lecture it's probably a good idea to take more notes to keep your mind on the topic; otherwise you're going to have too much spare capacity left and you're more likely to lose attention. So attention is an adaptive thing, and understanding attention gives us some notion of why people learn the way they do in studying assignments, in listening to lectures, and in other kinds of educational situations. There are whole courses on attention but this gives you some notion of how cognitive psychologists think about attention.

Another major topic is perception. Obviously I'm not going to have time to spend on each of these topics, I have written in my notes here skip perception if running behind schedule. This is a fascinating area for psychologists but it's a little less relevant to adult education, at least at an elementary level. Perception is concerned with how we organize incoming information, how we recognize things, how we construct out of meaningless material organized figures and patterns. But if you think of information coming in through the sense organs and some of it being selected in terms of its relevance to our primary and secondary tasks, the next major part of the information processing system that I want to talk about is "Working Memory" or "Short-term Memory." In a sense it involves some of the same things as attention.



You'll find some kind of diagram of this sort in textbooks and I'm going to talk to you in that sequence, but I don't want to give the impression that this is just a sequential process. One of the characteristics of human beings is that these things are all going on at the same time; they're interacting; they're part of a system that is not just a sequential system, but one in which the parts are interactive.

So, what do I mean by working memory? Let me give you some personal experience with this. This is an example that you probably had in your introductory psychology course. Almost everybody has. This is a demonstration that I used when I first began teaching psychology in 1946, and we're still using it. Now we use it as a demonstration of this modern concept of the working memory. It's called digit span. If I give you six numbers, you probably can repeat them back to me. Let's try it out: 3, 2, 2, 1, 0, 4. How many people think you could repeat it back? I won't test you.

Now try this. This time I'm going to give you ten numbers: 2, 2, 1, 8, 8, 7, 0, 1, 0, 2. How many of you think you could repeat those back? Probably one or two which is about right. How many think you could remember six of them? Probably not as many because one of the phenomena of this working memory is that there is a limited capacity and when it gets overloaded it seems to just push things out. You don't even get as much retained as when the capacity is fitted to the task. Let me give you that same series which was ten digits in a way which should enable you to remember all 10 of them. This is not the way we do it in the laboratory because you have already had practice at it, but it will demonstrate the principle anyway. I've going to give them to you in clusters. 221, 897, 01, 02. How many of you think that you could repeat that back to me? Well, quite a few of you. That's one of the principles of working memory; we call it "chunking."

George Miller, former president of the American Psychological Association, wrote a classic article, probably the most widely cited article in all of psychology, called "The Magic Number 7 + or - 2." He pointed out that a number of mental phenomena involve a capacity of approximately 7. You can remember about 7 digits in the digit span test. If I show you a visual display you can pick up about 7 elements of a visual display. There are other kinds of things as well which involve a capacity around 7. But, that doesn't mean that we can only say seven words to our students and expect them to remember that many words. We can do better than that if the material is organized. Chunking essentially is giving things in groups, giving things in an organized fashion, and it means that that capacity increases so that instead of seven separate digits you can probably remember five or six chunks of two digits or three digits; so you increase the capacity to maybe 10, 12, 15 or something of random numbers. Actually in some digit span tests that have been done recently they have trained subjects in the laboratory to remember up to 80 or 90 digits which is phenomenal! It is still hard for me to imagine that that is possible, but it is achieved through these techniques of grouping and familiarity.

Suppose I give you the sequence 2, 4, 6, 8, 10, 12, 14. How many digits do you think you're going to remember? Well, chances are, almost an infinite number. All you need is one principle of organization. Organization is part of the principle of encompassing things in one's working memory. A concept that links these two phenomena

is "automatization." Automatization is a mental process that has been so well practiced that things are chunked together and you can handle them without thinking of the separate elements as you had to do with the digit span test. Barbara's talking and driving is an example of carrying out two tasks which are both pretty well automatized. Most of us have driven so much that we can drive and talk at the same time. In fact, on the expressway going to the airport yesterday I passed a van where the guy was reading and driving. I think that's trusting automatization a little too much! However, in general we can take notes and listen at the same time because we have already learned the English language with its grammar and syntax so that we can pick up whole sentences as blocks, whole thoughts as blocks. We can write notes automatically because we've learned how to spell and, typically we've learned a system of taking notes that we can do almost automatically, so that the capacity needed for these tasks is much less than it would be if we were trying to take notes in another language. There is a good deal of evidence that taking notes schematically; that is, drawing arrows between things, making circles, maybe putting concepts in a hierarchical tree is more efficient, is better for learning, than simple outline note taking or key word note taking, the kinds of note taking we usually do. I've tried sometimes to have my students practice taking their notes in schematic form. What happens is that they get lost because when you try to begin to take notes schematically you find out that it takes too much capacity. When I use schematics, I run out of space on a page; I haven't got the concepts where I want them; and I've got to loop back around and insert things. The space just gets all messed up and I get so lost in the notes that I can't listen to what's going on. There's a book by Holley and Dansereau on schematic methods of representing concepts. My conclusion (in my chapter in the book) is that schematics are great if you've got at least 12 to 20 hours to practice such note taking. But if you need to take notes and you haven't practiced schematics before, you will not be able to handle the capacity that is required in using a new note taking system. Things that are automatized take less capacity and enable you to attend to larger blocks of things and increase the capacity that is available for the primary task.

The next element of the system is what I call "Long-term Memory." Long-term memory is where we store everything that has ever happened to us. Some theories of long-term memory say that we store permanently anything that we have ever learned--that we have stored say for more than a few seconds--such as a telephone number that we looked up and we kept rehearsing until we got to the telephone and dialed it and maybe looked it up again and dialed it later because it was busy and so forth. That telephone number is somewhere there in your mind. In fact, I once spoke to Dick Atkinson, who is Chancellor at the University of California in San Diego and one of the leading learning theorists, and said, "Dick, do you mean that somewhere in my head I've got a memory of every place I've ever parked my car?" He said, "Sure, if you remembered it long enough to get back at the end of the day or after shopping or something. That memory is there someplace."

Well, I still find that hard to believe because I've parked my car a lot of different places. I don't know. But it is clear that we have a lot of capacity and that there is a lot in our heads that most of the time we can't retrieve. The memory only comes out when we're able to restore the conditions under which it was learned.

One of the theories of memory is that if you have learned something in a variety of situations then it is more likely that you will be able to retrieve it later because there's a better chance that in the retrieval situation there are going to be some of the

same elements that were there when you learned it. That has implications for teaching in that it suggests that if students have not just rehearsed something over and over again but have heard different kinds of examples, have thought about it in different contexts, they're more likely to remember it and retrieve it.

One of the key concepts here in terms of how you get things from working memory into long-term memory and how you retrieve them is the concept called *elaboration*. An alternative theory which has a lot in common with the elaboration theory is called *depth of processing*. Elaboration/depth of processing theory says that if you're transferring something from working memory to long-term memory--if you're learning it--the more that you think about it, the more you relate it to other things that you know, or the more you question it or transform it into your own words, the more likely you are to remember it. That goes back to what I said about why note taking is a good thing. There have been experiments in which instructors have supplied complete notes to students; there have been experiments in which students have taken verbatim notes. If you compare verbatim notes or instructor-provided notes with students' own notes and with no notes, in general the students' own notes will come off better than instructor-provided or verbatim notes or transcripts. Why is that? Note taking works for two reasons. In the first place it acts as an external memory. If you have something in your notes you can go back and review for the exam. It's there and you don't have to get it out of your own head. You have some words that provide cues and that enable you to recall it. It provides extra cues for memory. It provides cues for review and that external part is probably the most important part of note taking. That's what most students assume note taking is for; something to review. But if that's all that note taking does, the verbatim notes or the instructor-provided notes should be better. The reason that the student's own notes work is twofold. First is of elaboration or deep processing. In taking notes, the student has to do something to extract information from the lecturer's words and to pick out key words or key ideas and put them into his or her own words. Students typically say, "I wish I could take shorthand. I'd be so much better off in a lecture." They would not be better off because if they were just taking shorthand, they would not be thinking about the material and trying to make sense out of it. The other reason that one's own notes are good is that it is a way of keeping attention on the task, particularly an easy task.

One of the difficulties students have when they subscribe to a note taking service which provides notes taken by an expert is that if they figure that somebody is going to give them the notes, there is a great tendency to go to sleep or not pay very much attention because they assume that the notes will be sufficient.

There are exceptions, as I said, and what the exception is depends upon what kind of notes you take. Generally speaking, if students organize material for themselves they do better than if the organization is provided. That runs counter to a lot of our stereotypes about good teaching because we think that a good teacher is somebody who is well-organized. But the data seem to indicate that providing an organization for students does not result in as good a memory or retrieval as an organization which the student has worked out for himself or herself. However, if a student has little background or is less able to organize things for himself or herself, that their notes don't represent the key concepts, they miss important qualifications.

Let me give you a tip; if you're lecturing to students, if you say something is *not* something, a significant proportion of your listeners are going to have in their notes that it is the thing that you said it was not.

We tend to miss the nots and so poor note taking often involves getting things just the opposite from what they are supposed to be in addition to sometimes being confused. So for the students with less background or less ability to organize, providing some organization is important. One of the reasons that I put key words on the blackboard is to provide a schematic organization. In general, Hartley's work suggests that for an ordinary heterogeneous class, the optimal solution to the problem of getting students to pay attention and develop their own organization without coming out confused is to provide a schematic outline in which the students have to fill in points.

We've talked, then, about attention, perception, working memory and long-term memory. We mentioned the concepts of *automatization* and *elaboration*. Those are key concepts that I see as being relevant if you're thinking about cognitive psychology as it relates to your own research plans. Let me, however, point out that there is another area that is also relevant to education and that also, I think, has made significant strides forward and which has also been influenced by this move toward cognition. That is the area of motivation. As I suggested, the theories of motivation when I was a student suggested that one is motivated because one has been rewarded for something in the past. The basic notion was that we respond to consequences. I ran an experiment once in which I tried to train some teaching assistants just to reward students--a good Skinnerian principle. Generally people work well when we cut down on punishing types of responses and provide more rewards. But it turned out that our reward strategy didn't seem to make any difference to students. In general, that kind of simple reward/punishment theory of motivation had limitations.

For example, sometimes a teacher looks at the paper of a poor student and says, "Oh, that's very good; you're making a lot of progress." Instead of thinking, "I've got to work harder because I've been rewarded," the student thinks, "The teachers must think I'm terribly dumb if they praise me for something so simple." We've found in motivation research as well as in learning research that the effects of consequence depend upon how people think about them and that in some cases reproving students is likely to encourage greater effort because it indicates that the teacher thinks they can do better.

I flunked my prelims when I was a doctoral student and I wasn't happy about it. The department chairman said, "Your performance was good enough that we'd probably let most people by, but we think you can do better so we're going to make you take another six months and take them over again." At the time I wasn't a good cognitive theorist so I did not appreciate that. But it would be an example of the cognitive approach to motivation. Now motivation theorists think much more about people's anticipations of the future and feel that behavior is guided much more by our sense of competence and what we anticipate is going to happen than what has happened in the past. I think this is particularly relevant to adult educators because as you deal with older adults one of their expectations is that intellectual abilities involving learning and thinking are going downhill as they get older. In fact, when I was a gradute student, we thought that intelligence dropped off after about age 19 so most of us, according to the old theories, are well into the decline of intelligence. Fortunately we now know that that theory is not true. Intelligence keeps going up, at least aspects of intelligence, probably until 80 or so depending upon the kinds of things done. You have probably heard the phrase "use it or lose it." As long as we're practicing verbal abilities, they tend to keep getting better as we get older and there's no reason why older people can't learn effectively. But if they have a

failure, older people are likely to feel it is an indication that their mind is not as good as it used to be and so there is no point in continuing to try to learn because they are simply going to get worse. This notion of *expectation* is a very important one in cognitive theory.

Let me now summarize some ideas from cognitive theory that seem to me to have potential value for adult education. One key idea is that *learning is a constructive process.* Students are like scientists in that they have already in their heads some notions of what the world is all about, some notions of what the subject matter you are trying to teach them is all about. They have these theories or hypotheses when they come into a course and they test them against what is in the course. They elaborate their theories; sometimes they buttress their own ideas and ignore those things that don't fit in with their own ideas; sometimes they revise their theories; sometimes they construct new theories as a result of their experiences in the course. If we're going to be effective teachers, we need to have an awareness of what is in the mind of the learners. Probably one of the key aspects of research is that instead of concentrating on instructional design in terms of the goals of the instructor and the nature of the subject matter, we should figure out what the students have in their heads. How are their ideas structured? How can we build a bridge between what we have in mind and in the course and what the students already know and what they are bringing to the learning experience? How are they going about constructing the knowledge that they're going to take away from the situation and from what we provide? Unless we know both ends--that is, what we have to offer educationally and how they're going about constructing the knowledge out of what we bring--we're not going to be successful as educators.

Research in adult education, from the perspective of cognitive theory, should be more focused on the student and less focused on the subject matter. This does not mean that all we have learned about instructional design and about establishing goals is irrelevant. What it means is that it is incomplete. In addition to looking at the instructional goals and the content, we need to look at the students' goals and the students' prior experience. One of the key things that we have learned in cognitive psychology about learning and problem solving is that the learners' prior experience, prior knowledge, and prior expectations are keys to their learning. That suggests also that one element we need to study is the students' studying. Learning involves what the students are doing, not only in the classroom but also out of the classroom. That doesn't mean that we should give up studying teaching, but our research lacks much more in understanding what students are doing to make material meaningful and how they're going about getting meaning out of the educational situation than in classroom learning.

Another research area is motivation. Now we realize much more that whether students are learning is a function of what they *want* to learn; not just the value they place on the learning experience but also their expectations about the chance of success if they devote effort to learning. In traditional decision-making terms, or economic terms, the student has to decide whether or not it is worthwhile investing time and effort, emotion and commitment, to a learning situation in terms of the likelihood of the payoff and the value of the payoff. My teaching assistants get very frustrated because some of their students do not do well on the first test. When the teacher suggests that the people who aren't doing well should come in, they don't come in. I suggest, "You have a couple of students who are doing very poorly; why don't you give them a call and set up an appointment?" So they call the students and the students won't come in. The TA's are

motivated and want to be helpful; but they're likely to get very frustrated and angry and almost punishing to these students who don't seem to want to make an effort. They blame the student for not being interested and not being motivated. I tell them, "This may not be a lack of motivation; this may be strong motivation to avoid a situation in which, according to the student's perception, failure is very likely to occur. "It is easier to come out of a course saying, 'Well, I got a D, but, you know, I just never got around to studying in the course; I didn't really think it was worth putting any effort into.' than it is to make an effort, talk to the teacher, try hard, and still fail. If you fail when you are really trying then that has implications for your own self-esteem and your own ability."

So in motivation theory we now realize that the students' sense of competence, of efficacy in the situation, is important. Thus we need a good deal of research on how you help students develop a sense of efficacy.

I was meeting with my teaching assistants this week to talk about my own course. I offer a freshman course called "Learning to Learn." In that course I'm trying to teach students cognitive psychology theory along with applications of it to their own learning in college. One of the problems is that the students who come in with the least background are probably developing some skills but they take the first test and they get a C. They take the second test and they get another C and they take the final exam and still get a C even though they've made good progress. We do not mark on a curve. Each test is actually measuring additional skills; probably the standards are somewhat higher so that as the term progresses grades don't give students a sense of progress. Particularly in classes where they are graded on a curve, they can be learning a good deal and still be on the bottom of the curve. How do you give them some sense that they are developing competence? My teaching assistants and I are talking about ways that will give students a greater sense that they're making progress, such as comments on their papers, multiple drafts rather than single drafts of term papers, things of this sort. We have students turn in journals every three weeks, and we have agreed that we want them to report upon how they're developing skill in reading and thinking about the course as a way of giving them some sense of the fact that they are making progress.

As I suggested, we need research on how students study and how they approach the material. We also need research on how students are motivated and how they can develop strategies for maintaining motivation. Barbara McCombs of the University of Denver has worked with basic skills education in the armed forces and has developed techniques which, I think, are effective not only there but would be effective for adult learners everywhere. She is working on getting students to establish goals; not only goals in terms of how this material is relevant to their life generally, but *subgoals* in terms of how they're going to achieve a particular standard of performance on a single unit, and even a goal for studying today. She has done some research that gives us a start on the notion that students can do a good deal to maintain their own motivation, but we still do not know a great deal about ways of helping students maintain their motivation.

A final suggestion is that in any course there are several levels of learning going on. We tend to focus on learning the *knowledge* in the course (and frequently knowledge is defined in terms of a multiple choice, true/false test that is primarily factual). We know now that these individual facts, individual bits of knowledge, are not retained very well and seldom are retrieved once the examination is over. If they're going to be retrieved and

learned and used later to form a basis for further learning, they need to be organized into *schemas*. Thus an important thing is the *structure* of the learning, the organization of the learning, rather than just the number of facts that are involved. So at the knowledge level we need to think about structure as well as number of facts. But in addition to the knowledge level, students are learning *skills* for further learning. They may be learning that in your course the thing to do is to read and reread an assignment and to memorize anything that is a list or a definition or they may be learning that it is important to think about how this relates to what has been going on previously. Some of the interesting experiments on deep processing have been done at the University of Gothenburg in Sweden by Ference Marton and his associates. Their research shows how students approach material differently depending upon what kind of test they're going to have. If they're going to have a test that involves thinking more broadly, such as an essay test, they are likely, in approaching their study, to look for relationships and see what the main point of the chapter is rather than just to memorize the individual facts.

So students are learning *how* to learn in my course. My course focuses on this second level; but it is not something that I think should be taught only in separate courses. I think learning how to learn is something that's going on in all courses. My own research right now is concerned with helping teachers in English, Biology, and Psychology to see how we can build in more emphasis on these skills of learning along with the content of their courses.

A third level we teach involves strategic learning. There are times when it pays to memorize things, and there are other times when it is better not to memorize but to try to think about the meaning. So part of what we're trying to do in most courses is to give students a greater sense not only of how to develop skills, but to know when and where to use them.

A fourth level of learning courses is motivation. Students get more interested or less interested. No matter how effective we are in presenting the knowledge aspects of the course, if we have led them to believe, "This is a boring area that I don't want to have anything more to do with," we probably have not been very successful, and they are likely going to forget the factual knowledge fairly rapidly.

I think there is some evidence (but we do need more research) that we can help teachers be more effective in all of these areas if they think about them, and are more explicit about what they're doing when they make assignments or carry out classroom activities. Why do term papers provide an important type of learning experience? Why is it important to have an essay test rather than a true/false test? Why do you expect that they should do some thinking about a textbook assignment and not just read and reread? Why is a laboratory experience worthwhile and what are the skills that students are expected to get out of it? When should they expect to use these skills later on?

The whole area of research on teaching and learning seems to me to be one that in the 40 years I have been involved in it has gotten more and more complicated. It started out originally as research to find out what was the most effective method of teaching. I found out long ago that that is not an answerable question. What is most effective depends upon what you are trying to do, what kinds of students you have, what the content is--a whole multitude of variables. At the same time that it has gotten more complicated, it has gotten more interesting. You will find there are a lot of interesting problems that are still unanswered.

BIOLOGY AND ADULT COGNITION

Frank Farley

Today I'm going to talk about brain and cognition and body and mind. One of the last questions at the end of Bill McKeachie's session was on the soul, an enormously important concept. It's not clear what the soul is but it's probably connected to the mind somehow or other.

On the way in, there was a group of MSU students outside and they said, "You're pretty duded up. What are you here for?" I said, "I'm giving a talk over at so and so hall." And they said, "Oh, yeah, what's it on?" I said, "It's on the brain and thinking." They said, "You mean like mind and matter?" I said, "Yeah." And they said, "Well what's mind?" I said, "No matter." And they said, "What's matter?" I replied "Never mind." Well, they're obviously brilliant students, always questioning. It's one of the central aspects of cognitive psychology, always questioning, always constructing and reconstructing, and it's alive and well in Montana.

There are a couple of preparatory comments I would like to make . . . to get my biases out on the chemistry bench here. I'd like to quote Nils Bohr. Bohr was not a bore by the way, but one of the great scientists of the 20th century, of the hard sciences, if people still believe that there is hard science versus soft science! Bohr used to preface his lectures with a wonderful statement. He was one of the really great open-minded scientists of our time, who said before many of his lectures, "Treat everything I say as a question." So I sort of follow that precept. My other bias or preparatory comment is also based on a 20th century physicist. I happen to believe in simplicity, and that things are simpler than they seem. I think there is much justification for that statement. Lord Rutherford, England's greatest contribution I suppose to 20th century physics, a great experimental physicist, had a dictum. He also believed in simplicity. I've sort of bolderized his dictum a little bit, but in a nutshell he said, "If you can't explain your theory to the local bartender, your theory has no chance of being proved true." I believe that. In fact I've been explaining my theory to my local bartender for some time, and he hasn't scotched any of my ideas yet!

There is one other related comment about simplicity. I think there's a great principle of art that's applicable to science; that is, in diversity lies unity. Behind complexity is simplicity. That is what we should be searching for. It is unfortunate that many professors seem to be in the business of making things more complex than they need to be. I remember as a student--I can barely remember as a student--professors always saying, "This is very complex." It often struck me at the time, I don't think that is what they should be saying. They should be in the business of trying to make things clear and simple. It is like current physics where they are attempting to find fundamental physical processes, and they are down to somewhere between four and six at this stage of the game. I think that is the kind of approach we should take. We should be looking for the hand behind things. We should be trying to get behind behavior. We shouldn't be too confused by all of those trees, instead we should stand back and look at the forest. There is enormous

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Frank Farley is Professor of Educational Psychology at the University of Wisconsin at Madison.

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"error" in nature, and we don't want to be swamped by error. If you focus too closely on the little things, you may lose the big picture. I think we should view things that way; go for the most simple explanations and try to relate things from different fields.

Well, when I get to my Type T Theory, if I get to it, you'll see that it's a simple theory in which I attempt to account for a wide range of phenomena. It's a deliberate strategy. I've tried to account for everything! Then we can cut back the parts of it that don't work and find out what is the true core.

Biological Research and Education

Today I'm going to outline some possibilities for connecting biological thinking and biological research to the research and theory of education and educators. Cognitive psychology, whose boundaries widen to increasingly encompass much of what scientific psychologists do, may have its finest hour in its contributions to the improvement of education. To educational research broadly defined, making education more effective, more enjoyable, and more appropriate to the mindscape of learners is a wonderful application of cognitive science and cognitive psychology. Unfortunately, much of education seems to be a battle between learners and learning. But the potential of cognitive psychology to ease the tensions is great. Galileo would have been pleased with this possibility. One might recall Galileo's requirement that all science be applied science. He defined the sole goal of science to be, "to lighten the toil of human existence." Well, this definition seems most appropriate to the consideration of learning and education, to lighten the toil of human existence. A caveat is needed here, however. The notion of *applying* cognitive psychology on the one hand, to education on the other hand, is to some extent inappropriate. Much of what is of interest and power in cognitive psychology and cognitive science has arisen from within educational concerns and discussion, a sort of phoenix that has arisen from the burnout of earlier behavioristic and humanistic education, as pointed out by Bill McKeachie this morning. Along with the increasing centrality of cognition in scientific psychology and in education has been a burgeoning development of theory and method in the brain sciences, a field of exponential growth in the past decade. Cognitive psychology and brain science are natural allies, indeed, some writers view them as two sides of a coin; complementary disciplines in the accounting of mental life. A concern for mind as contrasted with the attention of earlier decades to mindless behavior invokes a role for the brain. I think we all assume the mind is somehow connected to the brain. With cognitive processes presumably located inside the head we will need a brain science to fully comprehend them. Thus, in the past few years, we have seen "brain and cognition" develop as a fledgling body of knowledge, theory, and method.

Education, however, has had little consort with brain science. Brain science concepts and research are seldom referenced in the educational literature. Perhaps this is to be expected in the concern for supposedly rapid payoff in educational improvement that has characterized much of recent educational research. Brain science might seem remote to this concern. Indeed, why should an educational researcher be concerned about the brain and such seemingly esoteric disciplines as psychobiology, psychophysiology, neuropsychology, neurochemistry and the neurosciences generally? Well, the answer's that the best evidence indicates the brain is the center of human learning, memory, cognition, affect, attitudes, motivation, judgment, emotion, love, hate and last, but definitely not least, good research ideas.

In addition to this widespread under-

standing about the role of the brain in human affairs, it is also clear that we are in a revolution concerning our knowledge about the brain and the biological basis of human behavior generally. Educational research has always treated the neurosciences as the dark side of the moon. The brain is assumed to come into play in the learning process only when there is something wrong with it. We have pretty much left the brain out of the learner, out of the teacher, out of the administrator, and out of our data. I find our reluctance here astounding and ill-advised. As I mentioned earlier, there is currently exponential progress in the neurosciences; new conceptions of the biological bases of life, of the neural basis of behavior, have led to remarkable new science, to the direct manipulation of genetic matter, the transfer and mix and match of vital organs, the self-regulation of neural activity. These findings have led to an understanding of brain function that is light years beyond that of a mere half generation ago. For example, it has been estimated that in the last 20 years we've learned more about the brain than in all of recorded history.

So we have today a set of biological disciplines, some of whose work has significant implications for educational research. I believe it is high time we begin paying some attention to these efforts in our thinking about education. I believe that education in the years ahead will be radically altered by emerging psychobiological conceptions of what the brain can do and what we can do to the brain. Biochemical treatments, pharmacological treatments, electrophysiological treatments, biofeedback, self-control, neuromonitoring and neuroself-control, instructional conditions adapted to known features of central nervous system function, and the important identification of individual differences in central nervous system characteristics and the relevance of these individual differences to effective learning and instructions, will all eventually find their way into the lexicon of human cognition and educational improvement. I believe we can enter an era of the highest drama where the understanding and improvement of teaching and learning are concerned by including the brain in our equations for the enhancement of education.

Brain Research and Learning

The brain is a wonderful gismo, three and a half pounds approximately, very easily produced. Unskilled labor is all that is needed. One of my favorite definitions of a human was by a cyberneticist who said, "a human is a nonlinear servomechanical feedback system capable of mass production by unskilled labor." It's a wonderful thing, the brain. I estimate that we have almost 300 pounds of brain in this room today! It's incredible. With that 300 pounds of brain we could solve all of the human problems, I would hope. No computing machine is even light years from being in the league of this 300 pounds of matter.

Let's get down to nuts and bolts. How might we increase our attention to neuroscience concepts in our efforts to help learners and improve education? Well, one thing is certain. We will have to consider concepts and techniques that at first blush may seem unsuited or irrelevant to education and foreign to individuals trained in more traditional aspects of educational research. We might look at brain hemisphere differences and hemisphere specialization as one approach, you know, the left side of the brain and the right side of the brain. There has been a great deal written about this lately, but I'm afraid that many writers here have gone off the deep end, to use that wonderful old phrase, giving a role in education to hemispheric specialization that evidence for such specialization cannot carry off gracefully. Some individuals are designing complete curricula for left brain versus right

brain processing and our current knowledge of such processing differences cannot support these efforts. Perhaps we have here our old nemesis, an educational fad. I hope not. Suffice it to say that what is known for sure about left brain versus right brain functions, in terms of their implications for education, is fairly slim at present. Much of the research is fascinating and important but we need much more basic research here and much less rhetoric before we can enter these brain hemisphere factors into our educational considerations in a major way. I might point out however that some of the work to date suggests relationships between brain hemisphere differences and psychological factors, such as the spatial versus verbal performance idea, that had been identified years ago in traditional psychometric studies. Thus this particular aspect of hemispheric specialization fits nicely with some major findings of measurement research and work on abilities over the last 75 years.

I'd like to present a table that summarizes what we know. This is taken from the work of Jerre Levy [*Educational Leadership*, Jan. 1983, p. 68]. In my opinion, she is one of the leading brain hemisphere researchers of our time. This table is taken from a 1983 article by Levy in which are summarized the main things that we know for sure.

You'll notice that this is a relatively short list. So I am astounded when I go around the country to see people designing curricula based on putative left brain processes or right brain processes. I begin to wonder if some of these are really just half brain curricula! Then I get concerned about things like split brain reliability--you know there's all sorts of issues to be resolved here!

In addition to the possibilities of brain hemisphere research, one might look at some other psychobiological research and theory that bears upon a number of important conceptions in cognition and education. Gagne and Dick, in their 1983 review of instructional psychology, have outlined some of the concepts and research from cognitive psychology that are relevant to the psychology of instruction. Actually, some of these have been touched on by Bill McKeachie this morning. But they include cognitive strategies, problem solving, the idea of schema and schemata, knowledge compilation and automatization, automaticity of cognitive processes, among others. In studies of intellectual processes and individual differences, one might mention the approaches that have been labeled by Glaser, Sternberg, Pellegrino, and others as cognitive correlates, cognitive components, cognitive content, and cognitive training. Notions of expert systems, procedural knowledge, conceptual

- In the vast majority of right handers, speech is almost entirely confined to the left hemisphere.
- Right hemisphere processes add emotional and humorous overtones important for understanding the full meaning of oral and written communication.
- The two hemispheres differ in their perceptual roles but both sides are involved in the creation and appreciation of art and music.
- Both hemispheres are involved in thinking, logic, and reasoning.
- The right hemisphere seems to play a special role in emotion. If students are emotionally engaged, both sides of the brain will participate in the educational process regardless of subject matter.

knowledge, elementary and executive processes, attention, memory storage, conscious versus unconscious processing, are all central ideas and foci of investigations in current cognitive psychology, and in many cases, educational research. .

There is a growing body of neuroscience research bearing directly upon some of the foregoing ideas. Much of the most interesting process-oriented and measurement sophisticated research here has come from the neuroscience subdiscipline of psychophysiology. For example, Peter Lang has integrated some neurophysiological conceptions with cognitive psychology notions of text comprehension and imagery, examining his ideas through studies employing real time, electrophysiological measures of cortical processes as well as peripheral and autonomic functions. He has been generating some startling findings relating these biological processes to imagery and to comprehension.

Other relevant research has shown brain indicators and brain processes that are related to such cognitive functions as anticipation, memory load, mental effort, decision processes, hypostatization (a little philosophic term--the translation of the abstract into the concrete), the role of complexity in visual representations, and so on. In all of the foregoing the rapid development of microcomputers in education, and particularly the anticipated development of the artificial intelligence computer, will greatly facilitate the impact of such neuroscience research on learning and instruction. These rapidly evolving, agile little machines can provide a powerful mediating link for the real time interaction of brain and cognition in education. I'm very positive about the inroads of computers in education. Consider the much-awaited fully functioning artificial intelligence computer, the so called fifth generation computer, the thinking machine--Herb Simon thinks we'll have it, a fully functioning thinking machine. The implications of such a computer are fabulous for interacting with brain education. I think that such computers if they are developed are really going to unlock the human brain, in many regards, because much of our brain power seems to be locked up. Books have been wonderful and have helped a lot, but I think that the computer, if it is used in the interactive sense, will make an enormous contribution to unlocking our brain power.

One of the problems with relating the brain science revolution to the computer science revolution, these two great developments that I think are going to have a monumental impact on education, is that often there is no interaction between these two developments in educational contexts. Computer scientists often talk as if they're talking about the brain when they are talking about computers. Computer scientists and cognitive scientists generally are not integrating their work with brain science work, and that has been a problem in my judgment. Ultimately we must bring these two together. We can't let artificial intelligence lose its roots in real intelligence. But hopefully the study of the computer will help us to understand our own mental processes. Some brain scientists are not sanguine about that possibility and think that much of cognitive science is on the wrong track. The human does not think like a computer they say; the computer is based on one form of logic and only a part of our thinking may follow the same kinds of logic, so we may be on a dead end if we put all of our eggs into the artificial intelligence basket.

One very important aspect of educational research is that of individual differences and it is to this topic that I'd like to turn. A most productive tradition in educational research has been that of differential psychology and the study of individual differences and their educational sequelae, including research on measurement and prediction, the role of individual differences in learning and cognition, in

ATI or aptitude by treatment interaction models, and so forth. I think the area of individual differences may provide one entree for biological thinking into education. The right/left hemisphere concept has got a lot of potential too. I think it has yet to be fully realized. There are other possibilities. You might have heard of the work on brain growth spurts, the idea that the brain grows in spurts and plateaus and that you can link that up to the growth of mind. I don't feel that scientifically that linkage has led very far to date.

So, how are we going to connect the brain to education? Well, I have my own little scheme for doing that and it is based on individual differences and that long rich tradition of aptitudes which goes back to the turn of the century. We know a lot about aptitudes; we know a lot about measurement. It is probably one of the crowning glories of psychology. It is sometimes said that one of the few things that psychologists genuinely created was the IQ concept. But everybody steals from everybody else. I was in a symposium on cognitive science a few years ago at Berkeley and Lyle Bourne, a leading cognitive psychologist, was wrestling with how to define cognitive science. What is it? He had a little chart up on the board, and he had pictures, a diagram, arrows, connecting linguistics, anthropology, psychology, computer science, etc., all these things coming together to form the new cognitive science. There was much discussion and finally he said, "I don't know what cognitive science is. All I can tell you for sure is that a cognitive scientist is somebody who's willing to steal ideas from anyone!"

Biological Aptitudes

Well, we have this wonderful long history of research on aptitudes and so I'm going to use that. The entree that I'm going to propose of brain science into education will be based on what I call *biological aptitudes*. What I mean by that, biological aptitudes, are individual differences that have biological reference and measurement and that have predictive power for educationally relevant behavior and psychologically relevant behavior.

I'm going to run through a few candidates for biological aptitudes and I'll say a few words about each one as I go along. The basic idea is this: I believe you can measure biological and physiological processes of the nervous system and treat them as individual differences, get reliable measures of them; and then find how those measures predict or account for educational phenomenon. Now this is sort of looking ahead. This is probably not stuff that you're going to immediately institute in your research, let alone the schools and colleges. I think the main thing is to get the ideas out and see if you might come up with ways in which you could institute or use these ideas.

Brain evoked responses is one of the hottest topics these days in brain science. You can evoke a brain wave change through a specific stimulus. I won't go into the details, but you begin by establishing a person's brain wave baseline. A stimulus is presented, maybe a tone, and what happens is, you evoke a specific response. Now this response might look like any old random shape to some of you but believe me, there are dozens upon dozens of researchers whose whole lives are focused on such things. So you have evoked that phenomena and the wave returns to baseline. That is a very interesting sequence. As I say, it has become the focus of a great adventure in neuroscience as to what all of these different aspects of brain evoked responses indicate. Some research suggests that aspects of this may be correlated with intelligence (I am going to spend a few minutes on tha.t) and with decision processes; it may even be associated with schema revision, with the revisions of cognitive schema.

Another piece of research compared the evoked potentials of bright people, with

IQ's ranging from 142, 120, 125, 136, to low IQ individuals, with 85 and similar scores. They noticed a great difference between the two. The low IQ ones were smooth, but the high IQ's were jaggedy. Hendrickson and Hendrickson, British investigators, about six or seven years ago reported this analysis. They laid a piece of string from the beginning to the end of the wave and they measured how much string it took to cover that brain wave. (This sophisticated instrument they called the string test.) Then they would stretch the string out and they would correlate the length of the string with tested intelligence. It was correlated about .7 in their first study. Now that's a startling finding. In the scientific history of the 20th century, psychologists have been searching for a kind of holy grail, a connection between the mind and the body. People in Eastern philosophies have had their own ways of relating mind to body, but in the Western materialist world we have had trouble relating mind to body. It is hard to find correlations between psychological phenomena and biological phenomena. Here is one that just leaps right off the page at you. Well, they followed up. They did a replication using a different sample, different intelligence test, and have continued to report a high correlation. One was as high as .80+ in one study. Now this is still highly controversial research. Some people claim that they have not been able to get these results. It has not been replicated enough as far as I'm concerned, but if this holds up at all, it is a most interesting finding. What it suggests is that whatever underlies the shape of the evoked potential might be a sort of biological aptitude for intelligence. Now keep in mind this can take maybe 10 minutes to test in the laboratory. The individuals had a headphone set on and a pure tone and it elicited this. Now you can elicit evoked potentials using linguistic stimuli such as words, or other stimuli.

So, some people have said, "Wow! Maybe we have here a kind of universal index of intelligence." Other people have said, "This is the beginning of a true attempt to measure biological intelligence." It's still quite controversial but it is interesting nevertheless.

(Response to a question.) True. Hendrickson and Hendrickson have developed a biochemical theory that they say accounts for the jaggediness and it has something to do with error transmission in the central nervous system. I think they are assuming that biochemistry is somehow or other more basic. Their kind of reductionistic view is more basic than the psychology side of things. But I don't think they have dealt with the issue as to whether learning and experience could have an impact on that; it probably could. The brain has some plasticity to it and early experiences can change the brain. We're familiar with the work of Krech and Crutchfield at Berkeley where they environmentally stimulated rats. They stimulated some of the rats and others they did not stimulate and analyzed brain biochemistry. The stimulated rats lived in cages with all sorts of stuff hanging from the walls, a kind of enriched life of the laboratory rat, upscale yuppie rats with all sorts of stuff. The other ones were living in a very impoverished situation, as I recall it. At any rate, what the researchers found was that the environmental stimulation had an impact on brain biochemistry. So it is interactive in my view; the environment influences the brain, the brain influences the environment. What we have here in the human IQ work is a fascinating relationship that may or may not hold up. One big question to be addressed is, what causes what? That also assumes a sort of a billiard ball causality model. Some people aren't happy, including myself, with strict billiard ball causality: A hits B hits C hits D, and that's how it all works. Causality may be more parallel in nature. Some physicists are talking about time warps, or time going backwards, and all this kind of crazy stuff. The whole field

of quantum mechanics kind of ties in with that, so causality is no longer, in my judgment, a straightforward billiard ball kind of thing. Who knows what's causing this?

(Response to a question.) One of the problems in an intellective assessment is the biasing effect of language. Is it possible to get a nonverbal estimate of human intellective functioning and a universal intelligence index? Ideally you can measure the evoked potential in China, in Brooklyn, in Bozeman, all over the place. You can do it with infants, with the aged. In time we may have telemetry so you won't even have to hard-wire connect the electrodes (will that be 1984?). We'll get to that later in this presentation, I hope.

Back to the evoked potential briefly. I'll just mention that there are other things about this wave form that Emanuel Donchin at the University of Illinois has shown, a brilliant 20 year line of research on this phenomenon. He is particularly concerned with the so called P300 component but he has linked to an amazing array of cognitive and psychological phenomena. Aspects of decision processes seem to be reflected in certain parameters of this wave. He has claimed, I believe, that certain aspects of schema and the revision of schemata may be reflected here. So we may be getting into some of the brain bases of such powerful cognitive ideas as schema and schema revision. How does the brain indicate revision of schemas? That's an interesting question.

You have all seen drawings of a brain cell; presumably everything takes place here or in some aggregate of these. One of the interesting contemporary battles is whether learning, memory, and such are somehow or other "located" within the unit, the single unit analysis they call it, the single cell, or whether it's related to whole aggregates of cells. This argument rages back and forth. E. Roy John, a leading investigator, reported recently a study of rats in which he tested a very simple response, a little memory. He got the rat to learn something very simple but he found that vast areas of the rat brain were activated by that learning. So John believes that the brain is vastly involved in even simple memories. That is one view. Another view is that there are single cells in the brain specifically concerned with particular attributes of the environment, particular stimuli. And so that argument rages on.

If you check any textbook on the brain, you look at pictures of various brains, say a rat, cat, sheep, and human brain, and you'll notice the amazing similarity between the sheep and the human brain. (I'll leave you to draw your own conclusions on that one.) One of the crucial things about the brain and intelligence and evolution and so on is the relationship of the size of the brain to the body in an evolutionary sense. I mean the elephant has a bigger brain than we have but it is not that sharp. There is even some question about their memory!

Some brain theorists have identified various developmental areas of the human brain. The bottom inner area is often referred to as the reptilian brain, the old brain, the savage brain. The upper outer area is the thinking brain, the new brain. One fascinating theory is that in the course of evolution we still have within us our history; so we have within us our old reptile or savage brain. The continued presence of violence in the human condition is the assertion of the old brain which we are trying to keep the lid on through the development of the more recent new brain. This new brain is trying to keep the lid on the old brain, but the latter keeps reasserting itself in human affairs. So some people have argued that maybe we're in a kind of evolutionary race in which we've got to develop cognition and cognitive power, logic, reason, and so on in the new brain to gain control over savage emotions or we will blow ourselves into smithereens. Interesting theory.

Orienting Response/Defensive Reflex

Back to my biological aptitudes again. I'll whip through these and try to get to the type T personality.

Another aptitude is the "orienting response or defensive reflex." I don't have too much to say about that, but the Russians make a great deal of the orienting response (OR) and the defensive reflex (DR).

The orienting response seems to be the first reaction to a change in stimulation; it is highly connected to attention which is something that Bill talked about this morning as a major cognitive psychology topic these days. It may be related to discriminative ability and it is indexed in a physiological change. It is measurable in the body; we often use heart rate as an index. We've tested hundreds of people. Let me give you an example of heart rate change. If you're sitting in a room, quiet and relaxed, doing nothing, and you hear a scratching at the door, a whole host of things will happen in your body that you won't be aware of. The Russians say that blood will flow to the brain, out of the periphery into the brain, because you are getting ready to process information; something's happening. One interesting thing is your heart rate will typically slow down briefly. You may get a deceleration of heart rate just briefly and then it will pick up again. These are what might be called attributes of the orienting response. It is as though the whole organism is getting ready to process information. As I said, the Russians make a lot out of that. They say that if you are defective in the OR you may have trouble with subsequent cognitive development. Maybe it's reflecting some discriminative capacity. There are substantial individual differences in the orienting response. Some people show very strong orienting responses and others weak or no orienting responses to the same change in stimulation. If it reflects anything like discriminative ability, it means that if you are defective in the OR, you might have trouble making discriminations, so one would attempt to shape that orienting response.

Concerning the defensive reflex, let's say that that scratching continues and seems to be getting louder and then you begin seeing these long green fingernails coming through the door; it's going to change you right away. Your blood will go rushing out to the periphery, etc. A defensive reflex has occurred.

Well, there are various psychological phenomena that might be connected to the OR and DR attention, discriminative ability,intelligence. One of the most provocative studies has found a correlation between the magnitude of the orienting response and human intelligence. Now this piece of research by Herb Kimmel needs to be replicated in my view, but it found some interesting things. He reported a correlation between intelligence and strength of the orienting response using a very simple measure of the OR. (A number of these measures are very simple; you can hook them up to your computer and measure them while people are learning things.) He then shaped the orienting response using a particular shaping procedure. He strengthened the orienting response in low intelligence people and he found later that their intelligence had changed, improved, as well! That is a very provocative finding and desperately, I think, needs to be repeated by somebody.

The defensive reflex seems to be related to anxiety. Some research that Jenny Alexander and I did was to compare people who showed an OR with those who showed a DR to the same stimulus. Those who had the defensive reflex to those stimuli as opposed to the orienting reflex were more anxious people.

Autonomic Lability

Another biological aptitude is autonomic lability. I won't say much about

that but it has to do with how labile a person's autonomic nervous system is. Some people have very labile autonomic nervous systems. Labile means kind of reactive; very reactive nervous system. There are measures of autonomic lability in the literature. One of the things that it is related to, and this I think has enormous relevance to education you will all agree, is resistance to drowsiness under monotonous conditions. Star autonomic lability!

Biological Cycles

A biological cycle is not a two-wheeled device that a biologist rides to school every day. Rather it is a biological rhythm. A biological rhythm is a change in one's biology over time. We're familiar with the menstrual cycle for example, a well-known biological cycle. Very little research has been done on connecting biological cycles to education. It is a huge research area just awaiting somebody's attention.

You can measure biological cycles with a simple oral thermometer and temperature changes across the course of the day in certain systematic ways. But what is it related to? Research shows it is related to attention; it may be related to efficiency of learning, but that still awaits more research.

One of the interesting things is the idea of larks versus owls. The morning people versus the night people, or what Jean Shepherd, that peripatetic commentator on the American scene, once characterized as the night people versus the creeping meatballers. I have no idea what he meant by that, and I'm sure he didn't either. But he was talking about biological cycles in a sense. Some people peak in the morning; other people tend to peak later in the day. Well, we typically organize public schooling, K-12, around morning people. If larks peak at about midday, that means they are rising up to their peak and then they are beginning a slow decline from the peak. That almost correlates with the school day. But the owls, they're just beginning to get hot by around early to mid-afternoon and then they are sent home! The current school day does not seem to be the way to go for them. They *should* go home and study hard while they're still at their peak but they probably don't. They go and watch TV or do something else non-curricular. In adult education, there are lots of implications from this. It has to do with the scheduling of learning and instruction.

Electrocortical Coherence

The next biological aptitude is electrocortical coherence, which I'll just mention briefly. You can put electrodes on different parts of the head and correlate them to see where they are correlated. How coherent is the electrocortical data or reaction that you get? When you get high coherence, that is, high correlation among these measurements from different placements, this seems to be related to some important things. For example, mathematics ability has been related to this coherence measure. Creativity, concept learning--these are important cognitive ideas and they seem to be connected in with this coherence index to some extent, although replication and extension of the available research is needed.

Augmenting/Reducing Sensory Style

In 1967 a brilliant book appeared called *Individuality in Pain and Suffering* written by Asenath Petrie, an Israeli psychologist. She talked about how there seemed to be augmenting people and reducing people. Now this is not a diet plan or anything like that! It refers to the fact that some people when they're stimulated seem to augment the strength of the stimulation inside in the brain somehow. So, if I presented to you a 100 decibel sound right now and you were an augmenter, your perception of that 100 decibel sound

would be that it was louder than another person who was a reducer. It has nothing to do with the objective attributes of the stimulus. It is something inside the head bone between the ears.

Some people are augmenters; some are reducers. Petrie was interested in that because her lifelong interest, or one of her lifelong interests, had been in pain, an enormously important human problem. Pain researchers will tell you some people have tremendous resistance to pain and other people can't stand any pain. What is the basis of that? Well, research now indicates that it's a central process that is in the brain and it is actually a kind of style. It's almost like a learning style or a cognitive style. You can array people in terms of it. There are tests of it and you can pull out people who are the augmenters and those who are the reducers, and they will react differently in pain situations. It also is related to the ability to endure a sensory deprivation situation where you don't get a lot of stimulation and so on.

Nervous System Typologies

This is an enormously rich area. It really develops out of Russian and Eastern European psychology. When you ask a Russian or Polish psychologist what they mean by individual differences, they will typically talk nervous system types rather than intelligence or aptitude tests. They have a tradition of embedding individual differences in nervous system processes or in what they call properties of the nervous system. They believe that you can dimensionalize the nervous system and measure dimensions of nervous reaction. You can construct tests of these dimensions and you can use these tests in education, in industry, and in all sorts of situations. This two volume set of books that I co-edited with a fellow who's the head of the Psychology Department at the University of Warsaw, and one who is a professor at the University of Southampton, England, is the latest word on this topic. It appeared in 1985 and 1986 and in it we had the leading writers around the world, from Russia, the East European countries, and elsewhere, on this topic. It is fascinating; it is rich; it is quite different from the way we think about individual differences. Their belief is that you can, if you look at individual differences more in terms of the way the brain works, get around a whole lot of the problems that are associated with the way we do our individual differences work.

In the West we have so many problems in individual differences research such as biased tests. They're biased in favor of one ethnic group against another; they favor men against women or women against men; this, that, and the other thing. Researchers on nervous system types might say: "Let's get past these and get into the meat of where information is processed." Now it is very important to keep in mind that the brain is where everything of psychological importance goes on. Learning does not go on an overhead, on a blackboard, in a book, or on a computer screen. It goes on in the brain. The brain is the common denominator. We ignore it at our peril, and they are trying not to ignore it. So they have found all sorts of connections with emotion, motivation, perception. They talk about three basic dimensions in the central nervous system. They call them strength, balance, mobility. I don't have time to go into all of the differences and nuances there, but if you want you can take down the information on these two books afterwards. Strength of the nervous system, balance, mobility--these in various combinations, they believe, account for much of the richness of human personality and human motivation. They are actually taking these individual differences into account in work situations, in schools, in prisons, in a wide range of situations. And there are interesting tests and measures. They even tried to develop some questionnaire

measures. Jan Strelav, the fellow from Poland who was a co-editor of the books, has developed a personality test that he thinks measures some of those dimensions.

Type T Personality

What I would like to turn to now is the type T personality as my final biological aptitude. I could go on all afternoon and outline more about these biological aptitudes. One interesting question is, what glues these things together? What are the underlying processes that connect these? I'm afraid I don't have enough time today for that fascinating discussion. What I would like to do in the time remaining is go to the thing I've done most of my research on and which I call the type T personality.

There is a system in the brain called the arousal system. There is more than one arousal system. The arousal system that I'm going to refer to is the reticular activating system of the brain. (I have a handout if you want; it's a 1986 *Psychology Today* article.) There seem to be individual differences in reactivity of this system. Some people are highly arousable; some people are not very arousable; and other people are in the middle somewhere. That's my starting point.

I should point out I'm not married to the arousal theory in the brain. There is one thing about brain sciences that I've learned over the years. Never get wedded to anything too closely. There was once a well-known psychologist who developed a theory and got so wedded to it that when it started to be disproved in the literature he took out a knife and ran the knife into his heart and killed himself. I've learned from that; never take your theories too seriously! It is in the nature of theories, sadly, often to be disproved. So I'm not wedded to the arousal idea; in, fact there may be other biochemical processes that we may find are ultimately accounting for the type T personality. But, I believe, there is this dimension of arousability in the nervous system.

I believe there is a strong genetic factor here. In fact, where the type T personality is concerned, evidence suggests that there is significant heritability. I don't like to put a percentage figure on heritability estimates, but if I was forced up against the wall and a gun was at my head, I'd say probably anywhere from 40 to 60% heritability of the type T personality. My guess is that somehow or other it is connected with this arousal dimension. Kids I believe start off in life as being at one end of the scale or at the other or somewhere along in the middle. I further believe that for efficient processing of information we attempt to modulate arousal into some intermediate range. This is basically an old idea in psychology. It goes all the way back in some degree to the Yerkes Dodson Law of 1905. It is not exactly the same thing as the Yerkes Dodson Law, but the basic idea is that the relationship of arousal as I just described it and performance, were I to diagram it, looks kind of like an inverted U curve. That relates arousal to effective performance, effective psychological functioning. Now this is an abstract curve. It may not fit any particular person. The average, ideal curve looks something like that. So what that says is that there are low arousable kids in terms of this arousal system in the brain, high arousable kids, and other kids in between. This invented U function suggests that these kids who are low arousal persons will not perform very well. On the other hand, if you are a high arousal person, you also will not perform very well. But if you start off life right here in the middle, then you will be performing at maximum performance. So I believe that there is a sort of evolutionarily based process of attempting to modulate our arousal more towards the middle range from either end. If you are a low arousal person, therefore, you will try to increase your arousal.

I think the early environment can fine

tune the arousal system; nutrition, all sorts of things, can impact on it and influence your arousal level. But if you're too low for effective performance, I think that you will attempt to modulate your arousal to increase it. You will be an arousal seeker. On the other hand, if you start off life as a high arousal person, you are too high in arousal for effective performance. So you will attempt to modulate your arousal down. You will be an arousal avoider. I think that has survival and evolutionary significance. We need to process information effectively. Out there in the jungle, if you don't process information effectively, it has life or death consequences. You are eaten. Now, in the human jungle, it is more subtle. But if you don't process information effectively, you could end up on the bone heap of the human condition. Problems, lots of problems, personal problems. This, that and the other, who knows what?

So I think that we try to modulate our arousal into this intermediate range for effective functioning. I have liberalized the vertical axis from just simple performance to effective psychological functioning. So the people at one end, the low arousal end, I call "type T personalities," and the people up high I call "small t's." T stands for thrills. It also stands for transmutational thinking. (I'll get to that in a moment.) Thrills I think is what lies behind much of the stimulation seeking that these type T people do. It is not as if you suddenly become a type T, like you fall off a cliff and you're a type T or anything like that. It is a continuum. You can have more or less of these qualities and show more or less of these behaviors. These people in the middle I call the invulnerables or the survivors. Those are people who, no matter what you do to them, just truck right on through. They are the people who can take good education, bad education, noisy conditions, quiet conditions, nice beautiful pristine structured home life versus a totally disastrous home life, and they survive. They're the invulnerables. Those people don't need me so I don't do research on those people. I'm not certain these people at the two ends need me either, by the way, but I just won't leave them alone.

So, these seem to be quite different people. I don't have enough time to go into all of the differences but they differ on an amazing array of things. The big T--we'll call them the big T and the small t--the big T tend to be more impulsive, more creative, more delinquent. They think differently, these big T and the small t. They have different artistic preferences; they have a different sex life; they're just different on all sorts of things. It astounds me. It seems that the more things I throw at the type T personality concept, the more things I find falling out into two piles.

Someone asked, have we compared it to the Jungian system? We have just done a study in which we gave the Myers Briggs and type T measures to a large sample, but we didn't find very much. I can send you a copy of the paper we wrote up called *The Jungian Classification System and the Type T Personality.*

Anyway, on sex, for example, the big T types like more sex, more novelty in sex. Big T's marry big T's. Assortative mating is the technical term. We have done a lot of research on that and we've found that they tend to marry each other. If you think

High Arousal Value (Big T's Prefer)	Low Arousal Value (Little t's Prefer)
Uncertainty	Certainty
Unpredictability	Predictability
High Risk	Low Risk
Novelty	Familiarity
Much Variety	Little Variety
Complexity	Simplicity
Ambiguity	Clarity
Flexibility	Rigidity
Low Structure	High Structure
High Intensity	Low Intensity
High Conflict	Low Conflict

about it, that makes a lot of sense. Do you really want to have a big T married up with a small t? One wants a lot of variety and stimulation all the time, and the other one is strictly missionary position. It's not a match made in heaven. There are just differences all over the place on this. What then motivates these two groups differently? The big T are seeking stimulation and the small t are trying to reduce their arousal. So here is a compilation of ideas that I believe reflect arousal values.

Things on the left column, I believe, have high arousal value. I owe an enormous debt of gratitude to the late Dan Berlyne, who did brilliant work on the nature of stimulation and how it is related to physiological processes. Well, the things on the left I classify as having high arousal value. If you want to increase your arousal, you will seek these things--uncertainty, unpredictability, novelty, variety, risk, high intensity, complexity, low structure, ambiguity, flexibility, and conflict. So the things on the left, I believe, are the things that motivate, by and large, the big T personality. The things on the right would motivate more the small t--certitude, predictability, familiarity. Low risk, low intensity, simplicity, a lot of structure. These small t's like things to be neatly organized in nice packages and well laid out. They may show rigidity, they tend not to thrive on conflict. These two panels are enormously important for my type T theory because you can use these to spin out all sorts of things. You can use them to spin out ideas about instruction. If you have a big T person, these ideas should inform the way you deal with that person because this is what motivates. If you have a small t person who tends to avoid stimulation, and does not take risks, these things should inform you.

We have taken these factors and constructed measures of all sorts of things. For example, we do a lot of research on crime and violence. So we developed a measure of the arousal value of crimes, just spinning off of these basic ideas. We can give a crime arousal score; we then try to connect that to the arousal needs or these type T qualities of the perpetrator. You can use it to apply to media. We've done studies of advertising, of television, of the arts, even of theatre design, of live performances, of all sorts of things. You can use this as the basis for a rating scale for almost anything you can think of. For ideas. How certain is an idea; for example, how many loose ends are there, how open ended is it, or how structured?

Type T and Education

How would you go from here to education? Just thinking of these things, you can see why the big T tends to be creative. If you are not willing to expose yourself to the unknown, the uncertain, the unpredictable, you have almost no chance of doing creative work, great creative work. As Jacob Bronowsky described in his great television series *The Ascent of Man,* the great theoretical physicists of the 20th century, Fermi, Bohr, Einstein, lived their lives on the edge of uncertainty. Well, that is my definition of creativity. If you're going to do great creative work, you've got to be willing to expose yourself to the unknown, to uncertainty. Therefore, it is not surprising that big T personalities should be more creative.

I happen to believe that most of the great creative people in history are big T personalities. They were standing at the juncture of the momentous changes in history, in any field, because they were willing to risk; they were willing to engage the unknown. If you avoid the unknown, if you want everything certain, then you will not change history because you will abide by the existing structure and the existing rules. There is an important lesson here for American education. I don't know how impressed you are with American education, but I think that we have been on a plateau that's gone on long enough. Con-

temporary science and technology, have done fabulous things, but our educational system has not changed enough. I think creative risk taking, informed risk taking is something we miss in education of all levels, and we need more of an emphasis on that. I happen to believe that is America's great strength by the way, our willingness to take creative risks.

(Response to a question.) Criminal antisocial individuals--you're talking about the DSM III label--the antisocial personality. I call those the T minus. This may encompass delinquents, criminals, drinking and driving, unlimited drug experimentation, all sorts of things which I believe are tied in with the T minus quality. The T plus is associated with positive, constructive growth and creative development.

(Response to a question.) I'm glad you asked that. I think that is a problem with our understanding of stress. People seem to think that high intensity is stressful. It depends on who you are. Where are you coming from in terms of your stress? Some people love that kind of thing. They thrive on it. But we have, in the last few years, developed an idea that many of these kinds of things are stressful. I ask the question: "Stressful for whom and under what conditions?" For example, a type T in a very structured situation--that is stress. Or a small t in a highly ambiguous situation--that is stress. So when you get people in the work place and they are a big T personality, and they find themselves working on an assembly line in Detroit, that's stress. They are probably the people who are going to throw the wrench into the Cadillac carburetor. There has always been a problem with sabotage in Detroit, and it may be a big T responding to the unpleasant stress of the repetitive work. On the other hand, some people love repetitive work. They like clarity and they like things being laid out in a neat structured way. They like the old familiar ways; they like tradition and all of that; and that is great. They won't be stressed under those conditions but if you take those people and put them into an open ended, ambiguous, ever changing situation, they would just get stressed out. So that is my theory of stress. It is like an adaptive education model, that in the work place and in any kind of situation self-knowledge is enormously important and you should play to your strengths. If you are a stimulation seeking type T, don't get yourself into a small t job. If you're a small t person, don't get yourself into a big T job.

(Response to a question.) My guess is that schools are more designed for the people toward the small t end of the continuum or in the intermediate range. More so, perhaps, in private education where you can select people, versus public education where you have to take everybody who comes through the door. I think you are more likely to select these kind of people: the studious, on-task--you know, the ideal student using this model. If that is true, it has some interesting implications. It would suggest you're going to get more creativity in public education than you typically will in private education. You should get more conformity, you should get less delinquency in the private system than in the public. But I think the schools typically tend to play to the smaller t. Now for the kids in the middle, it doesn't matter. As I said, they're the invulnerables, they can survive anything. I believe the small t will do well in the traditional self-contained classroom with all the structure; think of the traditional library, that's built for a small t personality. But we know there are big T's; they are everywhere. They are the ones who like to study with the radio on or lying around on the floor. There is nothing wrong with that in terms of this theory.

Here are some of the things that I've broken out in terms of instructional procedures. These can be adapted for any age learner. Inductive instruction is ideal for the big T--discovery procedures, fast pace,

variable pace. Now again, we obviously are not going to restructure education this way at this time. But I've always believed that schooling changes mainly through simple ideas rather than trying to engineer great, huge procedures into education. You know the old R & D Centers back in the 60's: the dream was that you could take basic research and engineer it through into reality and change American education. It was all a great, huge, "Big Education" effort. I don't think that's the way education really changes. I think you change people's attitudes and outlooks, you change teachers' ideas, parent ideas, and so on. Piaget came along; he observed some kids and drew some profound conclusions from those observations. He changed education. People read his ideas and they said: Gee, that's great, I can use that idea in my teaching, or I can use that here, there, or elsewhere.

The engineering approach to education is bankrupt. It is not the way to go. I think basically we just have to change people's attitudes and cognitions about how kids think and how they behave. But we cannot rigidly adapt. If I put this into an adaptive education model or aptitude by treatment interaction, it would be very hard to get any school system to go along with a rigid system like that. But hopefully you could change the teachers' attitudes and they could try to adapt to each, to the big T and the small t child.

Computers will offer a lot here because the computer is a wonderful individualization tool. Diane Gamsky and I have done some interesting work with the computer and the type T personality. We find that so far there seems to be a notable sex difference. Big T females seem to love computers, much more than small t females. The big T females are really turned on by computers; they want to spend a lot of time with it. A computer has so many options. Big T's like options. They like degrees of freedom, they like elbow room, they have strong independence of judgement. We found that this whole system works beautifully for females on a computer, not for males. So far we find that big T males don't seem to be so interested in computers. It seems they would rather be out engaging in sports, or thrill sports, or adventures of one sort or another.

The learning environment can be adapted; computer based instruction can be adapted. So can teacher characteristics; type T teachers for type T kids basically. You want a lively, dramatic, engaging teacher for big T's and a somewhat more structured teacher for the small t.

So, these people down at this end where we've done most of our research on the big T phenomenon tend to be more delinquent, they tend to be more creative, they tend to think differently. I won't go into much of the delinquency research but we have done a number of studies on that and we find that the type T consistently is a factor.

Type T and Creativity

Where creativity is concerned, we've done a lot of research. We find the big T is related to creativity. The big T seems to think differently than the small t, and I'll give you a flavor of that. I call it *transmutative thinking* or transformational thinking. The big T seems to have a highly flexible form of thinking. Things seem to be related in the cognitions of the big T and they seem to be perhaps dissociated or unrelated in the cognitions of the small t. For example, we took Arthur Jensen's tests, the ones that a number of years ago he used to measure what he called level I and level II intelligence. His level I was presumably some kind of simple associative intelligence or associative learning and level II was more conceptual. For level I he used the digit span task and for level II he used Raven's Progressive Matrices. So we used his tests, ones that he provided to us. We found that among the big T persons in our sample, these tests were high-

ly correlated, .7 in the study we did. Among the small t's, they were totally uncorrelated, .1. That was pretty startling as it showed a powerful moderating effect of the type T dimension. It suggested that things seem to go together more in the mental life, if you will, of the big T. And things seem to be more separate in the mental life of the small t. So we followed up on that. We have done studies where we looked at difference between pictorial versus linguistic processing; that is the processing of pictures versus words. We found the same thing: the processing of pictures and words is significantly correlated among big T's, and totally uncorrelated among small t's. So this dimension seems to be associated with some sort of basic thinking processes.

Now if you think about the creativity findings of earlier research that we did with the big T, this kind of fits with that. Presumably, a creative person is somebody in whom mental processes are interrelated. It is the idea of metaphorical thinking, analogical thinking. These people can see relationships; they have many entry points to solving a problem. They are more likely, therefore, to be creative, to come up with creative solutions. In the small t person, everything seems to be processed in some separate way, almost as if these things are dissociated one from the other. (By the way, I happen to believe that these people at this small t end have a greater likelihood of schizophrenia. I won't go into that, but that might tie in with certain theories of the thought processes of schizophrenics too.) So big T's have this transmutative thinking. I believe that they can transform one conception of reality into another conception of reality with ease and flexibility.

But what is great creative science, great creative art? It's taking a reality, processing it, and coming up with a whole new conception. That's what Einstein did. In Einstein's wonderful year, 1905, he changed our whole conception of the universe; a sort of orgy of type T in one year.

(Response to a question.) That would fit. He's acting more like a mystic than a scientist. His whole life is going on in this transmutational matrix, if you will. Think of many of the great discoveries: Watson and Crick's discovery of DNA structure for example; they were at a dead end with the theory. They couldn't wrap it up until they put the thing together in a double helical structure, a physical model. Remember that? They looked at it and all of a sudden it was like the "aha" experience. They said, "That's it." They had taken the abstract, hypostatized it into the concrete, and that was the solution. So they were able to transform one reality, one cognitive representation, into another cognitive representation, and that revealed the solution. They then were able to go back from the double helical physical model to the abstract level and write their mathematics and that was the end of the greatest discovery in modern science.

I think much of scientific discovery and creative art is similar. Take Picasso . . . Picasso saw the same world that other people saw. When that went through his transformational matrix, it came out totally different, a whole new conception of reality. That, to my mind, is creativity and these big T people tend to have that. Aside from their seeking the unknown and the uncertain, which helps underwrite their creativity, they also think differently.

T Plus and T Minus

Also, there is T plus and T minus. I'm going to have to wrap up now, so I don't have time to go into that in any great detail. T plus, T minus, primarily mental, primarily physical. I talk about how people can seek stimulation primarily mentally. I call them the T mental and that is evidenced in great creative science and art, it's evidenced in entrepreneurship, financial risk taking, and so forth.

Now you cannot perfectly sort out the mental from the physical, the mind from the body. I mean, it's a wonderful old question, but we don't have any precise ways of sorting out mental from physical. Some people say sex is physical; essentially it's not. Any good sex therapist will tell you a lot of it is going on between the ears. So, you can't really sort these out perfectly, but you can talk, I think, about some people who are primarily mental stimulation seekers, mental T; others who are primarily physical. Evel Knievel is primarily a physical. Now it's rather interesting--I happen to believe that in the process of getting older there may be some shift more into the cognitive. Evel Knievel has given up being a daredevil. He's left that now and he's become an artist. He's going into entrepreneurship, too. He's linked up with Muhammad Ali, and the two of them have formed a corporation. They are producing commercial products. Many of the astronauts, a tremendous physical rush, have become more mental. For example, Alan Bean is an artist in Houston. Edgar Mitchell is a pursuer of the psychic in San Francisco. So that's the mental. Francis Crick, the co-discoverer of DNA structure, seems to be a classic type T. He's often changing his area. He's left DNA; he's left molecular biology; now he studies dreams. He says, "We've got to know why we dream." We've been dreaming for hundreds of years; what's the point of it all? So he is studying dreams.

Rasputin was a T minus. He was seeking his stimulation, and so on, in basically mental ways. He had low physicality and he was evil. He was trying to control the Russian court through psychological machinations. So he is my example of a T minus mental. The classic T minus mental would be the disembodied brain in the jar in science-fiction that is controlling the evil empire. You know, the jar, the brain pulsating, and everything. That would be a T minus mental with very little physicality. Bonnie and Clyde, tremendous physical stimulation seekers, off the scale type T. Fast cars, rapid shoot-outs. They'd go into a dusty southern town at high noon when the streets were full of people, hold up a bank and there would be shoot-outs and fast automobile chases. You might remember at the end of their T-careers when Bonnie and Clyde were finally caught, they'd been taking these risks and thumbing their fingers under the authorities' noses. The cops could not stop shooting them when they got them. The sheriff had to grab some of his deputies' guns and say, "Stop shooting, they're dead." I surmise the cops hated these risk taking kind of people . . . .

(Response to a question) We use tests or interviews to assess this. I go around the country sometimes and meet with people who seem to be great type T's. I spent a weekend with Rocky Aoki in New York City recently. Rocky is the founder of the Benihana restaurant chain. Rocky is an off-the-scale type T. He's also an immigrant, and I haven't gotten to that yet, but I believe immigrants tend to be type T. It often involves risk taking to leave the old ways and go to a new country. Furthermore, there is research evidence supporting that, that immigrants tend to be more type T than the stay-at-homes. Therefore, immigration policy becomes enormously important in this country. In a moment I'll get to my argument that this is a type T nation and that it is both our strength and our weakness. Well, back to Rocky. Rocky was a Japanese immigrant with little money who started the now very successful Benihana restaurant chain. He started his entrepreneurship in the U.S. with a push-cart in the Bronx! He's got some 50 plus restaurants in the U.S.; he's now branched out into Benihana frozen foods. But Rocky is more than a mental T as shown in his creative risk-taking entrepreneurship. He's an off the scale physical T. He has ballooned non-stop from Japan to the United States, crossing the Pacific Ocean. I mean, how many

people do that? He was the first. He was once one of the world's top offshore powerboat racers. One of his best friends is businessman/publisher Malcolm Forbes, who seems to have many of the same qualities (strong T mental and T physical). Remember Malcolm Forbes motorcycling across Russia, hot air ballooning in different countries? So here is Rocky Aoki. It's hard for me to give him tests, saying, "Now would you like to sit down? Here's a 15 item questionnaire." It's just very hard to do. So what I did instead was spend a couple of days with him. I would interview him in a very informal way. I find that sometimes you just cannot give tests to some people. It turns them off. College freshpersons often seem to be easier to test than some older students.

Anyway, I use all of these approaches to assessment. I've used physiological tests. We just completed a study using what we call the sweat bottle test. Now that's a very usable instrument. It takes but a few minutes to administer, and is a tough analogue for GSR, a classic arousal measure. I don't have time to go into it now, but I can give you references if you stay or if you ask me later. The sweat bottle test has been written up in journals like *Psychophysiology*. We have used it in many different settings: prisons, schools, work places--here and there and elsewhere. People can be trained to administer it to themselves as well.

Well, here's a model of the creative side, the T positive side. All of these things for years have been identified as being associated with the creative personality. Frank Barron has been one of the leading researchers in this area. You might remember some of his books such as *Artists in the Making*. There, and by others including our own work research, creative people have been shown to have high energy, preference for complexity, variety of interests, divergent thinking, nonconformity, risk taking, curiosity. In our research these are all attributes of the type T personality. I believe further that there are brain bases for it. Therefore, if true, that explicity embeds creativity in the central nervous system.

Conclusion

Well, let me wrap it up with the grand scheme. I believe that America is a type T nation and we need to understand that quality if we are ever to survive into the centuries ahead. I told you that I would use a simple approach. I'd take a straight forward idea like type T and try to account for everything. So now I'm attempting to account for everything: history, survival, all of those big ticket items. Crank the clock back a few hundred years to the people who discovered this country. They had to be type T. If you set out from Lisbon, Portugal on a 40 foot wooden bark, on the Atlantic Ocean and all you knew is that you were heading west, you might even fall off because they didn't know for sure. . .you had to be a type T. . .risk taking, stimulation seeking, adventurous, excitement seeking kind of person. You had to thrive on the unknown, the uncertain. Therefore, I think we were founded by type T persons. Not everybody was a type T and there were varying degrees of it, but I think that that was a powerful part of our origin. I earlier mentioned the genetic role. So type T comes rolling down through the centuries under some genetic influence. In addition, I think we've created a system of laws and government that is conducive to type T behavior. Type T's like freedom, lots of elbow room, they show independence of judgement, they like a lot of choice. We have created a system of laws that is probably more conducive to independence and freedom than most other countries in the world today; there is a lot of degrees of choice. If I am right, that says a lot about how we need to govern this country. If we tie up the people too much, in too many rules and regulations, we destroy the very thing that made this

country great.

A final word on immigrants. We are significantly a nation of immigrants, historically. Wave upon wave of immigrants have come to these shores. I think immigrants keep that type T flame alive. I was delighted to read a note in *Science Magazine* recently on immigrant entrepreneurs. Some demographer had done an analysis of entrepreneurship in America and it turned out that much of the entrepreneurial vitality can be laid at the doorstep of immigrants. So, that again reinforces the whole theory.

If I'm right, that relative to many other countries we can be reasonably thought of as a type T nation, then it means that we will be enormously creative--the T plus, tremendous creative energy on the one hand--and we will be enormously violent and destructive on the other hand; the T negative. These arise from the same source. I think everybody will agree with the T minus side of it. Wherever you go, people say, "What a violent country." Rosemary Gartner co-authored an important book recently called *Crime and Violence in Cross-National Perspective.* She traced crime statistics around the world for the last 75 years or so, and indeed we are right on the top of the charts! It is, however harder to get data on how creative we are, but I have taken a look at the Nobel Prize as one index of a kind of national creativity, if you will. It's probably as good as any other. Our analysis indicates that the United States almost owns the Nobel Prize! It shocked even me. What we did was an analysis over 75 years of the award, in three 25-year periods. In the last 25 years, almost 45% of all people receiving the Nobel Prize were American. Russia was less than 20%; Japan, as I recall, was less than 10%. There was no country even in shooting range of the United States. In fact, if you take a look at the curves, you would predict that within perhaps 10 years the United States might account for 50% or more of persons receiving the Nobel Prizes. You could propose all sorts of hypotheses as to why that is true, but even controlling for population, that is an outstanding figure.

So what we have to do, in my judgement, is increase this type T quality. This is our great strength and this is our great weakness. We have to inculcate creative, healthy risk taking. We have to inculcate positive stimulation seeking, the T positive, and at the same time hopefully we will be diminishing some of the T minus. Education has, I think, a tremendous role to play in all of this. The next century is going to be the second great Age of Exploration. I have no doubt about that. We are exploding into outer space and into inner space--the mind. For the type T personality, that is their natural venue. These are the kind of people who thrive in that sort of milieu of invention and discovery and exploration, and we need to encourage that development.

TECHNOLOGY AND ADULT COGNITION

Barbara Grabowski

The topic of this paper, "Technology and Adult Cognition," is an appropriate description of the current state of research in instructional technology. Past use and research focused on the external variables of media and their effect on learning, while the more current questions deal with the internal processing of information received from the media. What I would like to present in this paper are trends in media research which led up to this current state, describe current trends, and finally propose future directions of research with the latest interactive technology.

In order to address the topic, however, one must first have a clear understanding of the terms, technology and cognition, as they are being presented here. The use and definition of terms are consistent with those in the *Educational Technology: A Glossary of Terms* (1977). Technology is defined as the hardware and software used in instruction. Technology, however, takes on a broader definition in the field to include the process of designing and developing instruction. In an effort to narrow the scope of the topic as it relates to adult cognition, I choose to focus more on the hardware and software aspects of media. Media are defined, therefore, as the "physical tools of instructional technology." In other words, media include print, audio, video, film, slides, computer software, etc. The term cognition has been well defined by the preceding authors and is used here to mean the mental processes through which an individual obtains knowledge and understanding.

Barbara Grabowski is Associate Professor of Instructional Design, Development, and Evaluation at Syracuse University.

Past Media Research

In an effort to define a future research agenda, the first step is to critically review trends of research in the past. The media research history is long, the number of studies, vast. Although there are many researchers who have attempted to draw conclusions about this research, most of their conclusions were the same. They found that the questions asked were the wrong ones, the methodology flawed, and the results insignificant, along with one major problem being the lack of a unifying conceptual framework (Bovy, 1981; Clark, 1983; Clark and Snow, 1975; Fleming and Levie, 1978; Hannafin, 1985; Levie, 1987; Salomon and Clark, 1987; Salomon and Gardner, 1984; Schramm, 1977; Shlechter, 1986; Torkelson, 1987). In reviewing this list of researchers, it is most notable that these problems are still being discussed even in 1987. This is important because one still finds media comparison studies being conducted and reported in the literature even today. I would like to summarize some of the points of these researchers, not to prolong the discussion, but to use them to point to current trends and the promise for the future.

Much of this early research is summarized by a keystone report by Jamison, Suppes and Wells (1974). In their review, media comparison studies were synthesized using a technique Clark and Salomon (1987) call a "box score approach" to determine the most effective medium. The effectiveness of television was being compared to the traditional classroom.

Slides were compared to television, film, computers, etc. Few differences were found, with most of the studies resulting in no significant differences. Where significance was actually found, researchers concluded, mostly incorrectly, that it was the medium that made the difference, when in actuality, upon closer investigation, those results came from the instructional strategies used such as better organized material, prompting, repeated exposure, cuing strategies, interactions, advance organizers and not the technology itself (Bovy, 1981). When these other variables were held constant except for the medium, few differences were found. The conclusion is that, in fact, media are "mere vehicles" for the delivery of instruction (Clark and Salomon, 1987). Many researchers are now proposing that any objective can be taught with just about any medium (Bovy, 1981).

Other important and more current reviews of media research have been conducted by Kulik and several colleagues and are worth noting here (Kulik, Kulik, and Cohen, 1979, 1980; Cohen, Ebling, and Kulik, 1981; Kulik, Bangert, and Williams, 1983). Primarily, these studies synthesized research using the more advanced statistical techniques of meta-analysis. Results reported by these researchers showed some positive trends toward the use of computers. These results, however, are currently being challenged as also being confounded in an ongoing discussion in the literature by Kulik and Clark (1983).

The results of several decades of media research clearly indicate that learning was not caused by the medium but by other variables not yet defined. I turn now to current research trends.

Current Media Research

What is interesting, historically, is that there were researchers who were proposing that understanding learning from media was more complicated than simply studying gross media comparisons, although they were largely ignored (Torkelson, 1987). They suggested that learning involved an interaction between the individual and the stimulus material. Cognitive functioning was beginning, even then, to play a part in the investigation of the effectiveness of media.

In three excellent articles, Clark and Salomon (1987), Torkelson (1987), and Bovy (1981) summarize the impact of cognitive psychology on the changing focus of instructional media research. They trace the most significant beginnings with the evolution of three important theories: Goodman's symbol system theory (1968), Olson's theory of instruction means (1976), and Salomon's media attributes theory (1979), and further discuss the implication of information processing theories on learning from media and resulting research. What I will do is highlight some of those trends, and refer you to these summaries for the detail.

Briefly, Goodman suggested that a symbol was anything that could be used in a referential way, and therefore, symbols were the important variables to investigate in research rather than the medium which carried the symbols. The core of the theory centered around the notational values of the symbols. A symbol's notational value was determined by its direct correspondence to its referent. In other words, a symbol could have only one interpretation, as with musical notations, or many interpretations as with the symbols used in pictoral representation. Researchers were beginning to see the significance of the many interpretations of one picture by various individuals viewing it, thereby impacting on the variability of learning.

Olson's theory of instructional means also considered the individual, but in a different way. He contends that knowledge structure and the skills for interpreting symbols combine to yield understanding. As a learner observes a picture, knowledge

is conveyed, as well as skills for interpreting the picture. Without skills in the symbol system, no knowledge can be gained. His theory provides the basis for much of the visual literacy research of the seventies and eighties.

Salomon (1979) in his media attributes theory, combined the work of Goodman's symbol systems and Olson's theory of instructional means in an important way. Salomon based his theory on two assumptions: a) both the media and the human mind employ symbols to represent, store, and manipulate information; and b) some of the symbol systems employed in cognition are the symbol systems employed by media (Salomon and Clark, p. 468).

In evaluating or conducting research using this theory, one must closely evaluate the actual use of the symbol systems available with the various technologies. The differences in effectiveness between media, therefore, may be interpreted in the use of symbol systems unique to a particular medium. Using television simply as a means for delivering a person speaking should result in no difference in effectiveness than direct delivery, as was seen in many of the cases reported in early research. However, results may be different if the symbol systems such as zooming, cuts, fades, etc. are employed.

Another important contribution of Salomon's theory, which builds on his second assumption, deals with the use of symbols systems to develop cognitive strategies within the learners themselves. Some very positive results have been obtained in an often quoted study of zooming techniques by Salomon (1979). He found that Israeli children developed visual skills after being introduced to television for the first time. More research is definitely needed which investigates the training of higher cognitive processes using various symbol systems of the media.

From this, Salomon recommended studying the effects of media attributes on cognitive processes. What he was proposing in his approach was to identify unique attributes and combination of attributes of the various media, and to vary those to determine their effects. This approach has received much support, but unfortunately in all of my reading I have found little synthesis of results of systematically investigating those media attributes. One of the problems, as I see it, is that those media attributes have not been clearly defined. Most of the references to them are only "such as" examples.

Other Cognitive Processing Theories

Another body of research in the area of cognition as it impacts on technology deals with the levels of information processing. As was described in an earlier paper, information processing usually refers to the various stages or transformations information passes through prior to storage in the long term memory. These stages include short term sensory storage, short term memory, working memory, and long term memory. Currently, Salomon's use of symbol systems to aid in the processing of information is being challenged. What is suggested is that the use of symbols systems which match cognitive processing actually may supplant active cognitive processing and, thereby, impair learning (Bovy, 1981). Future research needs to consider, therefore, the use of media attributes at the various levels of information processing, especially if matching cognitive processes may have a mathemathanic effect on learning at the deeper levels of thinking.

Future Research

What was learned then, from these decades of research? The trend, fortunately, has moved away from conducting gross media comparison studies and toward the investigation of the effect of symbol systems used by the media on cognitive processing and vice versa. Salomon

(1979), therefore, suggests four areas of potential research:

-what and how people learn from media;

-what functions people attribute to media and the gratifications the media offer them;

-how adult's varying aptitudes interact with alternative media; and

-how the symbol systems of the media interact with the cognitive functions of their users.

With the development of the new technologies, specifically computer based interactive video, I believe that we have at our fingertips a very powerful tool for conducting research in adult cognition. I would like to address this area next. As a research tool for investigating symbol systems/media attributes and their effect on cognitive processes, the combination of interactive video and the computer is ideal. This powerful combination of media almost guarantees that the research questions generated will no longer be media comparison studies. A closer look at the new technology is warranted to understand why this is so.

Computer-based interactive video contains the capabilities of all of the other media, except for print. Since films, videotapes, and slide-tape programs can be stored on disc, visual images in the form of text, motion, stills, plus audio can be accessed. Treatments are, therefore, designed around the media attributes available rather than film, slides, or television. The computer combined with the videodisc adds a level of interactivity never before available with a single medium.

Besides the media attributes common to the individual media, additional attributes are available and can be put under greater control of the learner. For example, the learner can control fading in and out of a computer-generated graphic overlay onto a realistic image from the videodisc. Simplifying information in the instruction is at the direction of the students, and only if they need it. Learners can call up alternative representations of the same information, such as visual, auditory, or text-based descriptions for further clarification. Attention focusing devices can be automatically added if the student misses a concept or an idea. The important point here is the attention given to the learner as an individual interacting with the learning material and the design of learning material which more closely matches individual cognitive processing strategies.

The adaptive capability of the interactive video and the computer also offer exciting potential in the investigation of questions relating to modalities of learning and cognitive schema. With the data collection power of the computer to gather information regarding student responses, response times, response patterns, and store massive data bases of information that can be drawn upon relationally, an expert's structure of knowledge on a topic can be stored while a typology of how a learner approaches a task can be recorded and investigated. This exciting area is commonly known as intelligent computer assisted instruction or ICAI. For direction in this area we look to cognitive schema theory. With this technology, research can progress beyond just investigation of individual differences. Intra-individual differences proposed by Kyllonen, Lohman and Snow (1984), who suggest that an individual does not have just one cognitive style or process, but rather has many which change over time and over tasks, can be explored.

Conducting research in these areas will yield few important results unless it is conducted within a unifying conceptual framework to direct both the definition and the interpretation of the research studies. Following the guidance provided by Salomon's attributes theory, I believe that it will be important to define this conceptual framework around the media at-

tributes available within the computer-based interactive video medium. Given, also, the current state of research in media, this agenda should investigate the intersection of these media attributes with two other important variables: individual differences in terms of cognitive processing, and content type. Significant research on the interactions of these variables would contribute to an understanding of how individuals learn and how instruction should be designed. A very important next step is to specifically identify the relevant variables which would fall under each category and is the next task in my own research.

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ENHANCING COGNITIVE SKILLS

Richard A. Block

An important practical question for cognitive and educational psychologists is whether or not cognitive skills can be enhanced by various kinds of instruction (see, for example, Baron & Sternberg, 1987). This question has become increasingly important in recent years as many universities (including Montana State University) have taken steps to implement or to revise a general core curriculum for all students. Typically, a core program includes several basic skills courses such as writing, speech, and mathematics. Some universities--notably all of those in the California State University System--are now also requiring that all students take a course in critical thinking. There are probably several good reasons why there has been a tendency to require such a course. One reason is that many people have observed that college students often do not seem to acquire basic critical thinking skills as an inevitable result of a traditional university education. And there are probably many more adults who have never attended college who also demonstrate grossly deficient critical thinking skills. I have even observed this deficiency in the speeches and memoranda of a few university administrators, especially when they fail to appreciate my own insightful analysis of a situation.

I will begin by briefly describing the main characteristics of a thinking-skills course that I have been teaching at Montana State University. Then I will discuss some recent issues concerning the potential effectiveness of such courses. These issues stem from a consideration of the differences between the thinking of novices and experts on any particular subject. Finally, because I hope that at least some of you are interested in doing evaluative research, I will discuss advantages and disadvantages of different approaches to research on the effects of thinking-skills training.

Richard Block is Professor of Psychology at Montana State University.

Thinking Skills Course

For the past 13 years or so, I have taught an upper-division course on cognitive processes. As the field of cognitive science has matured, my course has included more and more direct instruction in practical thinking skills. Eventually, this practical training was simply occupying too much of the course, and I thought that this instruction could easily be offered in a separate course.

Several years ago, we decided to teach such a separate thinking-skills course. The first year, Shannon Taylor, who is from Business Management, was also involved in designing and teaching the course. The course is now a core curriculum course in the Social Sciences. It is not, however, required for all MSU students, as such a course would be in the California State University system.

In deciding what content to include in a beginning-level thinking-skills course, I naturally considered five major categories of cognitive skills. These five categories, then, formed the focus of the course: hypothesis formation and evaluation, judgment and decision making, problem solving, reasoning, and memory. I expect that this selection might gradually change as my teaching of general thinking skills evolves. However, these basic emphases of

the course have not changed much over the past several years.

I do not provide any direct training in other areas of cognitive psychology, those which seem less amenable to enhancement. These include skills involved in attention and perception, among others. At the present time, very little of the kind of appropriate applied work has been done in these other areas.

Cognitive Strategies

My general approach is to review very briefly cognitive research on any topic, especially research that concerns common pitfalls in thinking. Then I introduce the students to various strategies to guide thinking, I illustrate the situations in which certain strategies may be useful, and I provide examples and extensive practice in the use of these strategies.

Let me give you some examples. I attempt to enhance my students' reasoning skills by introducing them to a specific strategy involving Venn diagrams. I teach them a wide range of problem-solving heuristics, such as heuristics of simplification, working backward, and means-end analysis. I introduce them to a decision-making strategy involving decision trees. Because I cannot assume that all students have the same amount of knowledge in any particular domain, I try to generate examples from the shared experiences of all of our students, mostly involving everyday situations. I will have more to say about the issue of teaching thinking skills and the problem of domain-specific knowledge later.

Managerial Strategy

Some research--notably that of Schoenfeld (1979), a mathematics professor--suggests that students who are taught cognitive strategies may not be able to use them effectively. They seem to lack the metacognitive skills needed to organize their use of the strategies. In earlier times, the difficulty might have been seen to cause a failure of the instruction to "transfer" into the everyday realm. One possible solution to the problem is to accompany the instruction in cognitive strategies with a general metacognitive plan--what Schoenfeld calls a "managerial strategy," and what others call "executive control." A diagram of such a managerial strategy resembles a flow-chart depicting the major steps required from an initial analysis of a problem situation to the evaluation of a tentative solution. Recursive loops are explicitly built in to depict and circumvent the many dead-ends that even an expert might encounter. In the past, I have usually taught Schoenfeld's diagram, his managerial strategy; but on occasion I have also suggested that students construct their own overall plan, then compare it with one like Schoenfeld's.

Ecological Relevance

Another possible way of solving the "transfer" problem is to use many different kinds of everyday examples to illustrate the wide range of potential use of cognitive strategies. One generalization from some past research is that using abstract, puzzle-like problems with little "real-world" relevance seems contraindicated. Some of the previous attempts to teach general thinking skills were probably doomed to failure from the start because of the lack of ecological relevance of the exercises and examples.

I do not think that a thinking-skills course should merely attempt to improve performance on standard intelligence, aptitude, or even critical-thinking tests. Those kinds of tests often contain rather artificial items with little or no ecological validity. However, in my course I do use examples from standardized tests like the Graduate Record Examination, since tests like these are indeed very ecologically relevant for some of my students. Al-

though it is not a major goal, I would hope that my students might do better on such tests than they would without any thinking-skills instruction.

Writing and Thinking

Much recent work suggests that there is an intimate link between the development of skills needed to write clear expository prose and the development of effective thinking skills. This is what underlies the notion of "writing across the curriculum," which has been adopted here at MSU. Whenever possible I have tried to incorporate short writing assignments in my course. I think that this may be especially important whenever some more abstract or mathematical strategy or technique is taught, such as Bayes' theorem. In general, though, having to write a description of various techniques, various stages in problem solving, or various types of decisions probably brings students to a deeper understanding of the interrelationships among the components involved. Thus, writing assignments are an essential aspect of my thinking-skills course.

Thinking and Domain-Specific Knowledge

Some recent research on the cognitive processes of experts and the development of expert systems has become cited with greater frequency by cognitive scientists. This evidence seems to suggest that any attempt to teach general thinking skills is likely to fail. For example, Resnick (1983a) argued that cognitive performance depends intimately on knowledge related to a specific task, not merely "disembodied processes of thinking" (p. 478). This claim seems quite appropriate in the light of what is known about cognitive processes. However, in a subsequent letter Resnick (1983b) asserted that specific knowledge affects the form of a person's reasoning and that "if reasoning can be taught, it can probably only be done in the context of specific domains of knowledge" (p. 1006).

In a recent review article, Glaser (1984) suggested similarly that "thinking is greatly influenced by experience with new information" (p. 98). He argued that a broad spectrum of thinking skills might be more effectively enhanced while providing education in content-specific domains of knowledge than by teaching special thinking-skills courses or programs. In short, both Resnick and Glaser have argued that the available evidence suggests that it is futile to try to teach general thinking skills outside the context of domain-specific knowledge and training.

In a published comment of mine, I argued that there is actually very little evidence that thinking is *not* able to be enhanced by thinking-skills courses or programs (Block, 1985). Instead, the meager evidence that is available suggests that general thinking-skills courses or programs might have a substantial, positive effect that will be transferable into a variety of content-specific domains. What we desperately need at the present time is additional evidence that there are ways of teaching general thinking skills which will produce a long-lasting enhancement of students' ability to think effectively--and to do so in a wide variety of contexts and situations. Until we are able to provide that sort of evidence, the arguments of Resnick, Glaser, and others will necessarily be recognized as somewhat valid. I think that we need much more evidence before we can even begin to understand the complex relationships between general thinking-skills training, domain-specific knowledge, and transfer of training. And we certainly should not prematurely close the books on general thinking-skills courses.

Assessing Thinking-Skills Courses

Unfortunately, much of the crucial evidence that we need is extremely difficult to obtain. Let us take a critical look

at the assessment of thinking skills. As I argued earlier, it is essential that we assess the progress made in enhancing critical thinking skills of our students. The development of thinking-skills courses, whether designed for college students or non-college adults, must be accompanied by the use of appropriate evaluation techniques.

Subjective Techniques

Generally speaking, assessment can either be subjective or objective. The subjective techniques are interesting, but not very convincing to most people because of biases, demand characteristics, and so on. Subjective assessment can be obtained from the professor, the students, or both. It would be surprising indeed if the professor were not enthusiastic about the effects of the course, and I evaluate my thinking-skills course positively. My students, though, are also very positive. In addition to using a more traditional course evaluation form, I have asked my students: "Do you feel that you are a better thinker as a result of having taken this course?" Nearly all say "yes," and they cite such changes as: "I have learned to look in depth at problems," "I think things through," "I have learned more ways to solve problems and a more creative way of thinking," and so on. A positive attitude is important, and my students seem to have one.

Objective Techniques

Final Examination. Naturally, a skeptic will remain skeptical, so we need to use some objective kinds of measures. But what? We could compare the performance of students on a final course exam with that of a matched control group. However, if the exam contains items on which students received direct instruction, no one would be terribly surprised if their performance was better.

Performance in other courses. We could also look at a student's overall grade point average in the years following the course. Unfortunately, at many universities critical-thinking skills might tend to be punished rather than rewarded, especially if the student challenges a professor's thinking on some topic. Further, we cannot control differences in the difficulty level of courses which students elect to take.

Intelligence or critical-thinking tests. Another proposed way of assessing improvements in thinking is to see whether or not intelligence or critical-thinking test scores increase. Evidence indicates that, in fact, IQ scores do increase slightly as a result of some kinds of intensive problem-solving or thinking-skills programs (see Sternberg & Detterman, 1983). However, there is the lingering question of whether or not these improvements are merely the result of training in test items--what is called "teaching for the test"--rather than truly general enhancements of thinking skills.

Piagetian tasks. Much the same could be said about the apparent progression of some thinking-skills students from concrete operational thought into formal operational thought. Although this might reflect a broadly applicable enhancement of thinking skills, we again do not know to what extent the teaching program has taught students simply to perform well on the Piagetian tasks.

Thinking Skills and Knowledge Structures

The major problem with all of these assessment techniques is that one never knows the extent to which the thinking skills that have been taught are restricted in generality to those that are required to perform well on the test. There are a few ways around this problem, though.

First, one could explicitly teach only a subset of the skills--those necessary to perform well on about half of the item types

on the criterion test--and not teach another subset of skills--those necessary to perform well on another half of the item types on the test. Then one could see the extent to which thinking skills necessary to perform well on the latter subset of test-item types are either the same as or are transferable from the skills that were explicitly taught. The main drawback to this type of thinking-skills instruction is that it is still "teaching for the test"--even if only for about half of the item types on the test. Few instructors and even fewer students would find this kind of instruction satisfying.

There is another alternative, however. Rather than assess performance on a criterion test solely in terms of the number of correct responses, one could use multivariate statistical techniques, such as cluster analysis and factor analysis, to explore changes in the underlying structure of cognitive skills and knowledge.

One excellent example of this kind of technique is the work of Schoenfeld and Herrmann (1982). They were interested in differences between expert and novice mathematical problem solvers, specifically in the perception of problems and in the underlying "knowledge structures." Rather than testing their subjects on mathematical problems and scoring performance in terms of correct or incorrect answers, they asked subjects simply to categorize a number of mathematical problems. Subjects sorted the problems into different piles on the basis of their similarity. A cluster analysis revealed that mathematical novices tended to classify problems on the basis of "surface structure." However, both mathematics professors and students who had taken an intensive 18-day course on problem-solving strategies tended to classify the test problems according to principles relevant to problem solution--what might be called a "deep structure" of mathematics problems.

I think that Schoenfeld and Herrmann's research exhibits a powerful method for assessing changes in thinking skills in such a way that alternative explanations for the expected enhancements are ruled out. In addition, their research is a good example of the kind of work that is urgently needed on the relationship between general thinking skills and domain-specific knowledge.

Other recent research suggests that the kinds of problem-solving strategies that are used by novices differ from those used by experts. For example, novices work backward and use means-end analysis more often that experts do. Experts often are able to use a general rule or schema to simply and effortlessly work forward. This kind of qualitative difference between the cognitive processes of novices and experts is certainly interesting. However, I am not so sure that it suggests any ways of helping people make the transition from novices to experts.

Someone once said that the way to improve your problem-solving skills is to solve a lot of problems. There are certainly many people who have become expert thinkers and problem solvers without any explicit cognitive-skills training. Perhaps the role of the cognitive psychologist, then, should be a bit more modest--that of speeding the transition from novice to expert, and making it a bit less painful.

When I came to MSU and learned what the official slogan of the University here is, I was rather appalled. Most universities have a nice, esoteric Latin slogan on their official seal. Well, we don't. But now that I think about it, perhaps it's not such a bad slogan after all: "Education for Efficiency." What I have been trying to do in my course can be thought of as enhancing the efficiency of thinking skills, in much the same sense that experts in a particular domain are able to perform more efficiently than novices.

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HOW WE SOLVE PROBLEMS

Charles E. Moon

There are at least four areas of cognition that my colleagues and I have been working on over the past five years: (a) problem solving in a specific content domain, (b) automaticity in verbal processing, (c) training in drawing inferences, and (d) the moderating influence of field dependence-independence on aptitude-achievement relationships. I will briefly summarize a research investigation representing each of these areas, then suggest possible extensions into adult populations.

Phyllis Karns was a member of the nursing faculty when she entered our doctoral program. She noted that professional nursing associations were assuming that baccalaureate degree nurses were better problem solvers than associate degree nurses. The baccalaureate degree nurse presumably has had more theory, more content, and greater exposure to opportunities to develop problem solving skills relevant to nursing than the associate degree nurse, who has been regarded as little more than a technician. The research question she attempted to answer was: Do baccalaureate degree prepared nurses differ from associate degree prepared nurses in problem solving performance as measured by a latent image branching simulation of a patient management problem?

Twenty-four associate degree nurses and 31 baccalaureate degree nurses from selected Wyoming hospitals completed the simulation instrument, which features a novel situation calling for two nursing diagnoses, construct validity evidence, and an objective scoring procedure. A hierarchical multiple regression analysis was conducted, statistically controlling for age, years of health related work experience prior to nursing, years of nursing, years of higher education, and area of hospital work. Educational preparation contributed significantly to the explained variance in problem solving performance after partialing out the covariates, with baccalaureate prepared nurses scoring higher on the average than associate prepared nurses. Approximately 8% of the variance in problem solving performance was accounted for by educational preparation, with the effects of the covariates removed from both problem solving and educational preparation.

In addition, a content analysis of the "problem space" and pathways taken by the subjects revealed that 59% of the baccalaureate prepared nurses and 41% of the associate prepared nurses took the most efficient pathway to the correct diagnoses.

While critical cues were used in the formulation of tentative hypotheses by most subjects, there was evidence of premature closure on the part of many subjects relative to final diagnoses.

In an investigation of the effects of familiar vs. unfamiliar stimulus words and practice on automaticity in verbal processing, Richard Hall used a single task/dual task paradigm, presenting verbal decoding tasks both orally and visually with reading level as a covariate and reaction time the dependent variable. The limited processing capacity of attention and the efficacy of automaticity in expert problem solvers provided the theoretical basis for this study.

Charles Moon is Associate Professor of Educational Foundations and Instructional Technology at the University of Wyoming.

The subjects were thirty 6th and 7th-grade University School students for whom reading scores on the Stanford Achievement Test were available. Each subject's reaction time was measured in miliseconds at each level of the independent variables, so that there were repeated measures on familiar/unfamiliar word conditions, single task/dual conditions, and practice trials, for each of orally presented and visually presented verbal decoding tasks. Order of treatments was randomized over subjects. Treatment implementation and reaction time were managed by a computer program written specifically for this experiment.

The analyses of covariance, with reading level as the covariate, of reaction time produced the same pattern of results for the oral and visual decoding tasks. There was a significant practice effect, familiarity effect, and single task effect for each type of task. That is, reaction time decreased over practice trials, from unfamiliar to familiar conditions, and from dual task to single task conditions. When reading level is partialed from both reaction time and each within-subjects variable, single/dual task accounted for 25% of the RT variance, familiarity/unfamiliarity 32% of the RT variance, and practice 34% of the RT variance for the visually presented tasks. The corresponding effect sizes for the orally presented tasks were 12% for single/dual, 21% for familiar/unfamiliar, and 28% for practice. A serendipitous finding was a significant practice by familiarity by single/dual interaction for oral and a familiarity by single/dual interaction for visual. While we chose to interpret these interactions as limitations to generalizability of the main effects, they may have implications for theory-based aptitude-treatment interaction research.

Hoping to increase the verbal abilities and mathematical problem solving abilities of adult basic education students, Charlotte Farr designed an experiment that contrasted learning vocabulary from context and inferential reasoning with traditional approaches to teaching vocabulary acquisition. She based her investigation on a well-substantiated relationship between verbal and mathematics abilities and on a part of Sternberg's triarchic theory of intelligence.

Forty students were pretested on researcher-constructed measures of verbal abilities and mathematics problem solving abilities, 21 of these students received training in making inferences with analogies and neologisms, and the remaining 19 students received the conventional instructional sequence. Following eight weeks of application of the randomly assigned treatment conditions, the students were post tested with parallel-forms of the verbal and mathematics measures. High, middle, and low reading achievement levels were identified and built into the design to increase control and sensitivity of the statistical tests.

A 2 by 3 multivariate analysis of covariance revealed no significant difference between treatment conditions. However, there was a positive linear relationship between reading ability and vocabulary acquisition via correctly completing analogies and neologisms for both treatment groups. High ability readers tended to use a more analytic approach and low ability readers a more holistic approach. In addition, high ability readers tended to use an exhaustive strategy and low ability readers an associative one.

In another study, Farr investigated field dependence/independence, a cognitive style construct, in relation to achievement and aptitude among adult basic education students. Sixty students in an ABE/GED program were measured with the Group Embedded Figures Test to assess FDI and the Test of Adult Basic Education to assess vocabulary, referencing, facts, main ideas, and inferencing. Later, these students were measured with the Test of General Educational Development to assess achievement in mathe-

matics, writing, reading, social studies, and natural science. FDI was found to be related to both mathematics and reading achievement, as well as inferencing. Canonical correlation analysis was used to tease out the relationships between the TABE scales on the one hand and GEFT and the GED scales on the other. About 58% of the variance was shared by the first canonical variates.

Possible extensions of these studies to research on adult populations are:

1. developing problem solving tests based on simulations in other professional content areas such as engineering, teaching, and law;
2. examining automaticity in adults, with a theoretical framework that includes substantive and credible interaction involving familiarity and single/dual task variables with novice and expert problem solvers;
3. appraising the effects of metacognitive training on verbal and mathematical problem solving abilities;
4. making training programs designed to increase intellectual functioning more potent by prolonging as well as intensifying the treatment, and providing a distinct contrast with a control;
5. describing and controlling populations and samples of adults in terms of salient characteristics and consistent participation in research studies;
6. sing field dependence/independence to test for interactions with instructional methods in affecting cognitive outcomes;
7. combining qualitative research methods with quantitative research methods in investigating a set of research problems;
8. using research to improve theory, and theory to improve research;
9. developing novel ways of collecting data, including using the personal computer in more flexible approaches; and
10. aggregating existing results in a philosophy of meta-analysis, and replicate, **replicate, REPLICATE!**

FROM RESEARCH TO PRACTICE: THE PRACTITIONER'S PERSPECTIVE

Joanne Erickson

The challenge to the practitioner is to take the research that is presented to us at various conferences like this and others and attempt to modify practices in the field because of that exposure. The results are sometimes very exciting and sometimes very frustrating. Research has, however, influenced practice and helped teachers solve day-to-day problems.

One of the goals of this conference is to encourage research in adult cognition but also to insure that the research that is disseminated is used. It is helpful, then, to examine some of the ways the research is actually being used by practitioners as a means to bridge the gap between research and practice.

Professor McKeachie spoke on the importance of motivation and the adult learner. To illustrate that point, let us consider the case of the English Second Language (ESL) students enrolled in post-secondary vocational education. These students frequently do not have the basic skills necessary to be successful in the post-secondary vocational educational programs that they are attempting. An example that we can cite is in the health related and office related training programs. The ESL students generally have the skills to do the manipulative part of the program but not the needed basic skills to do the reading, and to understand the specific vocabulary and the basic concepts. The student is thus unsuccessful in the curriculum. The obvious solution is to remove the student from the vocational curriculum and place him or her in a basic skills program to improve reading, writing, and math skills. That is reasonable enough from our perspective. From the point of view of educators, that is obviously what should be done. However, that doesn't work for the students because it fails to recognize an important point that Professor McKeachie talked about yesterday: basic skill development is not what the student is motivated to do. The student is obviously motivated to obtain skills that will get them a job; they fail to see the connection between the basic skills they must obtain and being successful in the vocational curriculum. Without the motivation to continue, they drop out. Research has helped the teachers solve this problem. Recognizing the importance of learner motivation, basic skill and vocational skill programs are being integrated so that the motivational needs of the student are kept in mind. Hopefully this awareness and subsequent programmatic modifications will help us retain students and provide them with both the basic and vocational skills they need for employment.

A second problem that practitioners in the field of adult learning are struggling with is teaching writing skills to adults. There is new emphasis in every arena for teaching writing. In adult basic education the emphasis is fueled because of the writing component of the GED test.

Some of the research on teaching writing to adults says, quite simply, the way to teach adults to write is to have them write; in other words, practice. The problem of teaching writing to adults exemplifies another of the key components of adult cognition: that of perception. It is pretty hard

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JoAnne Erickson is Director of Educational Services at Havre, Montana Public Schools.

to teach a student to write when their perception is, "I cannot write." They've never been successful as writers because any writing they have done lacked critical components that are important such as spelling, grammar, and punctuation. But, research now indicates that we should assign the students writing, have them write, and do not correct the grammar, punctuation, or spelling for a long time until they become practiced writers and until, in fact, they feel very comfortable about writing.

Practitioners are now using this research and finding quite remarkable success. Teachers are finding that by using the practice of uncorrected writing, those students who have the perception of "I cannot write; I just can't do that," are altering that perception and are then starting to feel confident about their writing abilities. When they start to become successful and get positive feedback about their ideas, (the content rather than the structure), the instructors can move on to work with structure. In fact, one teacher reported to me that the results are far better than ever expected. I'm hearing that from many other sources. So, here is a situation where research has been applied to solve problems.

The variety of prior knowledge that the adult learner brings into the learning setting has great importance to the practitioner. It is the challenge of the teacher to devise a program that is appropriate for the individual needs of each learner. One of our programs in the state did quite an involved research study on entrance testing (placement testing) tools. Years ago, before we had anything that was normed to adults, they used instruments like the California Achievement Test (CAT test). When the Test of Adult Basic Education (TABE) test hit the market, it was the test of choice for most adult educators as a diagnostic tool.

However, some of the teachers in this program felt that their analysis of student achievement based on classroom performance and on teacher devised testing did not correlate very well with results on the TABE test. Because of this discrepancy, they weren't very comfortable using the TABE test to devise individualized programs for their students. This particular project started looking at different standardized tests for adults and then tried to compare the various standardized tests against criterion referenced tests to see which standardized tests might be more reflective of their own assessments of entry level knowledge. In fact, in this particular setting practitioners have now stopped using the TABE and are using the ABLE (Adult Basic Learning Evaluation which is produced by Psychological Corporation), because they find that it is a closer match to their own measurements of prior knowledge and can better diagnose existing skills and needs of the adult learners they serve.

Yesterday Dr. Farley talked about brain functioning and personality characteristics and it brought to mind another study that one of my colleagues is doing on learning styles and personality styles that was motivated by the current research in this area. This particular practitioner uses two different instruments; one that is primarily academic and relates to learning styles, and another that is more related to personality style. The objective of the teacher involved in this study is to enhance metacognition; i.e., to try to help adult learners understand how they learn. Because of greater awareness of their own cognitive processes, they should learn better. This teacher also attempts to adjust her teaching style so she can maximize student success with their own learning style. Adjustment of her teaching style is not the main objective so she is willing to accept some incompatibility. Her major objective is to help students learn to learn, help them to be more aware themselves of their own learning styles and how they can use this to become more successful students

and more active learners. The research on metacognition has certainly enriched our understanding of how our adult learners learn and has helped teachers improve their teaching and learners improve their learning.

Technology is another area where practitioners are using research to improve practice. A recent pilot project in our state evolved out of a study done at Washington State University regarding the barriers to adult learning in rural settings. Billings, the largest city in Montana and the largest adult education program, undertook a project to deliver GED education via public broadcast television. Students interested in participating in the project phoned in from rural communities to the Billings Adult Learning Center and were given the times the programs were to be aired. They paid a small fee of $13 for related books and materials. These isolated learners were then able to participate in basic education lessons by turning on their television sets each day. There was no live audio or visual interaction.

Two hundred and sixty-seven people enrolled in this particular opportunity to study for the GED via satellite TV in their homes. People in 22 different rural communities in southeastern Montana were involved. None of these sites had any other kind of access to adult basic education centers providing organized instruction. Of these 267 individuals, 39 actually completed the GED in this first year.

Here are some of the questions that need to be answered regarding this project. Is 39 out of 267 to be considered successful or not? What was learned by the other participants who did not complete the GED? Was there learning there that actually fulfilled these students' goals? The stated objective was to complete the GED, but were there other objectives that were fulfilled with this particular program?

There is a need to evaluate how people felt about the use of the technology for basic education. One of the things that the project is attempting to do is to identify a volunteer within some of these 22 sites to assist and to encourage the students and thus hopefully to improve goal attainment. They also are attempting to get students to network with other students within these 22 communities. These measures are to compensate for the lack of interactive opportunities with the technology being used. Currently, the only interactive opportunity students have is to send their workbooks to the Billings center for correction. This still does not provide them with any live interactive opportunities for feedback and encouragement.

The learning center involved in this pilot program feels that the program was a success. They were able to determine that the 267 people that participated estimated that their books were passed to an average of four other people. In other words, one person bought a set of books, and four others in addition to themselves used these materials. The actual measured impact of the project was to provide basic skill education to some degree to 1335 adult learners. That is pretty remarkable when you consider the rural nature of the area involved in this study. The actual outcomes for the people involved need to be identified but the results of this project provide these adult educators with encouragement to continue to examine the research on technology and adult learners and also the research on overcoming barriers to education for the adults they want to be able to serve.

While these are a few examples of successful application of research to practice, it cannot be taken for granted that teachers will put the research that we now have and are currently attempting to develop into practice. Adult education teachers in our state, as well as elsewhere, are attempting to react to an enormous population growth. They are reeling under sheer numbers of students to serve, struggling to devise individualized programs for every student, to provide

needed counseling and support services and, in general, are reacting to day-to-day problems as they arise. They rarely have the luxury of time to examine the current research and plan how that research can be applied in their classes. Additionally, not all teachers have the skills necessary to implement the research and some will not automatically accept the results of research.

Including the teacher in the development, testing, and implementation of research is critical to develop a wider acceptance and use of educational research. Research should be designed in a way that it is useful to teachers in order to insure that it will be used. Furthermore, teachers need support in learning complex new teaching behaviors. I would encourage teachers to develop a "self-help community" or what Bruce Joyce refers to as "coaching teams" when they attend a research conference. These team members could then support each other in acquiring new skills, adapting the research to fit their unique situations, assisting in observing and recording results, evaluating success, and providing technical feedback to one other. While the primary goal of this conference is to encourage research, that objective is for naught if the valuable findings that are a result of the research are ignored by the audience for whom they are ultimately designed--the practitioner. It is encouraging to note that researchers of adult education recognize the need to bridge the gap between research and practice and consider the practitioners that must implement the findings of their research as adult learners themselves. Involving teachers in the planning stages of research as is being done here should initiate greater understanding and acceptance of research findings.

DOING RESEARCH IN ADULT LEARNING

An Interrogator Panel

Panelists: Wilbert McKeachie, Frank Farley, Barbara Grabowski
Interrogator: Gary Conti

Conti: For several years now we in adult education have used the term "andragogy," which we got from Malcolm Knowles, to talk about the teaching and learning of adults. Knowles has suggested that there are several characteristics that make adult learners different. (1) They tend to move from a state of dependency to being self-directing human beings. (2) They learn according to the social roles and duties they are facing. (3) They have tremendous reservoirs of experience which affect their learning. (4) They seek immediate application of things they learn. If these traits are so, how do we tie the concepts and research ideas from cognitive sciences to these elements? Or should we even be looking at these characteristics?

McKeachie: You should be looking at them. Malcolm has not done any research on them, as far as I know. I don't think these principles are absolutely true. I do not have the experience with older adults that many of you have had, but increasingly we are getting larger numbers of older students in our classes. This was especially true when I taught Psychology of Aging. There is a great deal of truth in what Malcolm says, but the notion that all adults learn in this same way is hard to accept. I find, for example, that some adult learners are very intellectually curious and not all that concerned about immediate application. They are able to think about applications because they do have all that built-in experience. That helps me as a teacher because they can make applications from material I present. But my conclusion is these are topics that need to be investigated rather than assumptions that should be taken for granted.

One of my areas of research is anxiety, and I feel that is one of the major things inhibiting self-direction in learning. There is a kind of challenge versus retreat--a reaction to uncertainties--in which adult learners become anxious about the learning situation. They are likely to ask for more and more directions; yet the task is one of trying to help them develop enough confidence so that they can begin to do things on their own and develop some self-corrective learning skills. That is an area that can be studied. One of the things that we found is that anxious students tend to lack some of the skills in learning that lead to success. As a result they have good reason to be anxious because, even though they spend a lot of time studying, they study by reading and rereading and memorizing. If you teach them some study skills, that tends to reduce their anxiety. We can get a bit of change on a measure that is called "Need for Cognition" which is a type of self-directed learning. As I recall, we didn't get nearly as much change as I had hoped for, but at least it is a topic for further research.

Grabowski: I would agree that they are important areas to be looked at, especially that whole area of prior knowledge. Adults come to the classroom with well developed cognitive schema. What does that have to say for how you should treat them? How do you adapt to what they know? Or *should* you adapt to what they

know? Certainly these prior schema do affect how they learn.

Farley: I would say: work out ways to measure these four principles and get on with research about them.

Conti: Do you have any other insights on how we could measure some of these concepts?

Grabowski: One of the things that is interesting about independent learning is the need for working in a group and the independent learning environment of computer-assisted instruction. That doesn't contribute to measurement but it is another question. How does working alone relate to the principles of andragogy?

Farley: In terms of measures, there are all sorts of things you could look at. We seem to be stuck on self-directed learning. The other topics seem to be less difficult to measure to me, such as prior knowledge or prior experience. But you could look at things like locus of control and intrinsic motivation concepts. There is a rich fertile area of theory in intrinsic motivation. Deci (that's not Washington D.C. but Edward Deci) has done very productive and useful research on intrinsic motivation. I think that would be worth looking at. There are measures in that area.

There is also attribution. What have been the success experiences of adult learners coming to learning and what are their expectations. If I had to name the biggest, most important psychological concept that I could lay on adult education, it would be motivation. People aren't machines and you can't fine tune them. I don't like the term, knowledge engineering; in fact, I find it quite an unpalatable term. I don't think you engineer knowledge. So motivation is one of the big areas to focus on. That really is captured in many of the points that you mentioned. There are lots of measures in the field of motivation--measures like intrinsic motivation, locus of control, attribution, attributional styles--that can be very useful in research with an adult learner. If you read any of Bernard Weiner's most recent works and check out his references you will find all sorts of things that will lead you to good measures. There is a wonderful book called *Personality Tests In Print* which is very useful. Also there is the *Mental Measurements Yearbook* and so on.

Conti: Here is a more specific question from the audience: How will I recognize an expert when I see one? What are the characteristics that differentiate an expert from a novice thinker?

McKeachie: Clearly there are experts in different fields. The earliest studies were on chess players. The hypothesis was that the expert would be looking a lot more moves ahead. It turned out they don't look further ahead than ordinary chess players, but the big difference is that they see the board as a pattern. And that is why they can play a lot of blindfold games at the same time. It doesn't mean that they have better memory for chess boards generally; they have better memory for chess patterns that are real playing patterns. If you scattered chess pieces around randomly, they can't remember them any better than anybody else can. So, it is experience in getting at the thing as a whole. The problem with the expert/novice difference, is that such studies do not necessarily tell you how to get there except to have a lot of experience at it. There is a Dutch psychologist named Dellshov, who has a term that I like. He calls it the "zone of probablisity." What he says is that for anyone tackling a problem or a set of problems, there are some problems that aren't problems for that person because he has done them so many times he can do them automatically. Now two and two isn't a problem for you; four just pops into your head. If you're an automobile mechanic and you deal with a certain kind of car, there are certain things that you just know what to do. You don't have to think about it. It's automatized; you see the problem right away and you know the

answer. He says above that zone there is a zone where you don't know the answer and there may be several different ways to approach the problem. For some kinds of problems there may even be several different answers that would be good. Then, he says, above that is a zone where there is no way you know how to tackle the problem. It is no longer a problem because it is unsolvable for you. He says the difference between the expert and the novice is that in this domain of expertise, whether it's teaching or chess or physics or what have you, the novice has very little that he or she can do automatically, A range of probablisity, and a big range of problems that are just beyond capability. For example, a calculus problem; if you only have arithmetic you probably wouldn't be able to solve it no matter what you do.

Grabowski: From a practical perspective, the researchers at Concordia University are developing "expert" systems, and their strategy is to try to extract information from people that they call experts. What they do is select five individuals who are leaders in a particular field. Then they try to extract this information and put it into relationships or concepts created on large maps. These five experts try to create the schema. At that point then the knowledge engineer's job is to extract the information.

Farley: I'd like to mention that David Berliner has been doing research on the expert teacher. He has an article called, "In Search of the Expert Pedagogue." He is one of the only people I know of who's looking exclusively at classroom teaching and expert versus novice differences in classroom teaching.

McKeachie: Berliner showed, for example, that if you show an experienced teacher a picture of a classroom, they pick up things that a student teacher or non-experienced teacher doesn't pick up. They see the classroom and what's going on in a more patterned, and actually more detailed way, than the students do. So in some ways it's like the chess experts.

Conti: Another question we have is: To what extent are critical thinking models gender oriented? I guess we could include our "big T little t" theories here too.

Grabowski: There is much research being done on gender. I have looked through the titles of the last AERA conference and there were a quite a few papers on gender differences.

Farley: It is an interesting question because it might imply that there are profound differences in thinking attributable to gender. I don't know if that would be true or not. Clearly there's a lot of interest in gender differences. Carol Gilligan has raised the whole issue of conceptions of moral development, and cognitive development generally, from a gender perspective. She has found some significant differences there. But, I must say that my own sense of it is that there are probably more individual differences in cognitive processes within the gender than there are between. That is just my guess. I can't see that in an evolutionary perspective there would be any reason to show sharp differences in gender in such things as thinking and cognition.

Grabowski: You have to be careful of the tests that you use when you are looking at gender. One of the things that Gilligan has done in her writing is to say don't look at the results alone but look at who designed the tests and materials they were using.

Farley: The tests may not be good operationalizations of the theories. The theories may be gender specific but the findings may show no difference because the tests aren't sensitive to the theory.

McKeachie: I say the same thing about "type t" so let me give Frank a chance to get his ire up.

It seems to me we go through trends. When I was in school the authoritarian personality was popular. Then I did research on need achievements. More recently people have been entranced with

the Myers-Briggs. Frank was indicating yesterday that there isn't all that much to left brain/right brain, but people are still interested in the idea. Actually I have a student working on the Myers-Briggs. I think all of these are ways of trying to pick up some key individual differences (including field dependent/independent that we heard about this morning). They are all good starts in getting teachers to think about the fact that students are not a homogeneous mass. So, it is useful to have some kind of system, usually a dichotomous one, whether it's t plus/t minus, or extraversion/introversion, or male/female. But this is only a very gross start. If you get more differentiations, it is probably better. But the danger is you begin to think: "Okay, I've got these persons classified. He's left brain, she's right brain; I've got to teach this one this way and this one this way; and then I've got the problem solved." People tend to get trapped into thinking they've got the answer once they've got the person typed by the particular learning style, or personality characteristics, or motive, or gender, or whatever it is. As Frank said, the big thing is that within any of these categories you've got wide ranges of people and a lot of overlapping. So it's good to start off thinking, "I've got these kinds." But then you need to go beyond that to say, "Okay, I'll try this because this is a woman or this is a man," or "I'll try this because this is a type t plus or a type t minus," or what have you. But then to see how it works and to change your strategy once you tried it. It gives you a start on strategy but you should not get trapped into the notion that that's all you have to do.

Farley: I agree totally. We have to start somewhere; humans differ. In education, we can't treat every kid differently in a full manner; we have to group. To paraphrase an MSU symbol, "Education for efficiency," we might call it education with efficiency in the sense that ultimately, I hope, it would be education for understanding. But we have to start somewhere. The value of studying individual differences and dimensionalizing human behavior is to use this information. We need information about the person. We have to have some sense of the person, and that is all that I think these things are doing.

You said when you were in school extraversion was the big thing. Extraversion still is a big thing. In fact, I think one of the crowning glories of seventy-five years of personality research has been the identification of a relatively finite set of relatively reliable dimensions along which people can be reasonably reliably located. That is really one of the grand accomplishments of psychology. We have had many other things that have gone by the wayside. I am reminded of a famous APA presidential address entitled "The Rise and Fall of the Laws of Learning," by one Wilbert J. McKeachie. For a long time we thought we had the laws of learning. I remember taking classes where we talked of the laws of learning. Well, where are the laws of learning? They're gone and Bill McKeachie wrote the epitaph and the obit for them. Now we have cognition and cognitive psychology and we'll see how far that goes. Hopefully all of these things add a little bit to prior knowledge.

In terms of individual differences, I think we have shown substantial, cumulative development over the last seventy-five years. We are more sophisticated in measurement; we have been able to connect these individual differences to biological attributes to some extent. In the history of science that's an enormous accomplishment because ultimately psychology can not be treated in isolation; education can not be isolated. All of these things are part of the whole and full accounting of human behavior and thinking. We do have fads and things come and go, but there is cumulative progress.

McKeachie: I think what is important is to do research on these things. I'm

an individual difference psychologist too. I work with anxiety. As I worked with it, I started out thinking all I have to do is get a general test of anxiety. Then I found out that there are anxious students who have good study skills and they are different from anxious students who don't have good study skills. There are differences between people who are anxious in testing situations and those who are anxious in the learning situation. You find out that if you do research you're not as likely to get trapped into over simplified notions. So I think that any area such as field independence/field dependence or left brain/right brain has led to good research. But some people have kind of picked them up and have run off with them. Well, the same thing happened with Skinner. Skinner himself is really a brilliant man, and as you talk to him you know he can really handle things. But you talk to his disciples and it's quite different!

Farley: An important thing is that one doesn't willy-nilly select measures to do this and that, and run correlations, and think that's the end of it. There should be a theoretical background that is powerful, and you should have some sense that you are going somewhere with it. I would propose more time be spent thinking about the design of the research than is spent carrying out the research. We need more elegant studies and less just throwing a bunch of variables together and doing multi-variate and factor analyses or something like that. Spend more time thinking about what the question is that you have, and what is the most efficient design to get there, and then do it. Often you'll find that you get powerful, profound answers without some enormous number crunching operation. My hero in psychology is Donald Head whose whole life was spent with simple, elegant, beautiful experiments, and that man turned around the history of psychology in many areas. His whole thing was to think of the cleanest, neatest, most elegant study. Unfortunately computers have seduced us somewhat into a number crunching science.

McKeachie: That's ideal, but I don't know that it is realistic for all of us. It's fine if people go out and do studies without a lot of thinking about it if they think about it afterwards. I read an article last night that was sent to me by the *Journal of Educational Psychology*. There was really nothing wrong with the whole thing. It had a good review of the literature, a good hypothesis, a good design, but the discussion and conclusions did not show any thought at all. I think the plus part is that research never comes out the way you think it will. You throw in some things that you thought might work and they come out differently. Then you think about it and come up with good conceptualization. I think of research as a heuristic device for getting you to think about why things are more complicated or different than the way you thought they were when you started. Thinking at the front end is good, as Frank said, but I think it's also important to think at the back end.

Farley: I think the problem, or the statement of the question, is crucial. Research isn't very hard to do. Research is just a way of trying to find out information about things. There are all sorts of forms of research; for example Journalism is a form of research. But the question is the crucial thing; so is problem finding. Many of the greatest scientists in the hard sciences really focused on that side of things; they were more concerned about finding the big issue. Again, I mention Jacob Burnowski's television series. Burnowski, himself a great scientist, put on a series called "Descent of Man" in which he made this point over and over again. He said one of the things we know of the great scientists is that they have a sense of what the crucial problem is.

Many people are out there doing research on this or that trivial thing. The thing is to focus in on what you think are the big ticket issues in adult education.

What are the really important things? Don't lose your way with trivial stuff. You can have the most elegant design with the maximum fancy-dancy, multi-variate statistics, and it still means nothing because you're not dealing with an important problem. Jack Casells has talked about this in art. He called it problem finding in art and has done studies of it. Working in the Chicago Art Institute he has found that the artists there who had a sense of what the problems were in art were the ones who later became the great artists. They weren't so hung up on technique and all that sort of stuff, but they had a sense of what were the areas that had not been explored in the field of art.

Another issue that we can associate with this is we don't have a science of discovery. We really only have a science of verification. We work out all the statistics for verifying whether we found a significant difference; we don't have a science for identifying the important problem. To me, the way we get into research is crucial because, once you're in there, the game is pretty much over.

Conti: Here are a series of questions from the audience. What are the big questions we adult educators should be asking related to cognitive science? Should we be using the naturalistic paradigm or the more rationalistic paradigm? Should we concentrate on a few things or a variety of designs?

McKeachie: There's a danger right now that cognitive psychology could get trapped into focusing on more and more and getting less and less. After a while research in an area can get to be boring because you're into such esoteric little aspects of your theory that it doesn't relate to anything. So there is an important contribution that educational researchers can make to cognitive psychology: try to keep a bridge between reality and the laboratory situation.

I don't agree with Frank that studies using reaction time are irrelevant. I think the measurement of reaction time enables us to tap into the stream of consciousness in ways that we could not before. It is clear that reaction time studies are not going to be things that you are going to want to do in adult education most of the time. We need knowledge about processes people use in real adult learning situations and not just in psychology or education courses. We need to know about areas that involve different styles of thinking and different relationships between the knowledge structures and application.

Farley: I did not use the word, irrelevant, as I recall, but I'll just say that reaction time was around in 1895; it's been around for almost a hundred years. I am not convinced that it is a tool of choice for modern cognitive psychology although I realize a lot of people use it. But again, I think we have grand ideas and we're testing them with very trivial methodology.

McKeachie: It is not trivial; it is really very precise methodology.

Farley: There is a need to be precise but what does it tell us about the complexities of the brain? Reaction time was great at the turn of the century, but I think we have wonderful ways of tapping in on the stream of consciousness. For example, real time verbal utterances can be recorded by a computer, and you can introduce various manipulations of a cognitive science or a cognitive psychology type, and so on. But it would be real time stuff that could be recorded or could be interacted with in a computer situation. That would be my dream of getting into the stream of consciousness, rather than by asking something and measuring a reaction time with a simple one word response.

One area of research in adult education that is quite relevant is the idea of the autonomous learner. That's an important concept in cognitive psychology and motivation. There is some literature in cognitive psychology from that area that would be relevant to adult education--the independent, autonomous learner.

McKeachie: One of the things I'm interested in that I think would be relevant in adult education is thinking and learning to learn. We know from the research on intelligence over the life span that there are differences in terms of people and how different intellectual skills continue to grow or drop off. We also note from the research with the older learners that these skills can be recaptured. But I don't think we have done very much in terms of trying to be precise about what kinds of learning skills adult learners bring to learning situations in addition to their general knowledge. What kinds of ways we can help them to gain skills in getting information? For example, if you're training people to be mechanics or computer operators they are probably going to have to get a lot of information from printed materials. We have developed some strategies that are good for reading a history assignment or a psychology assignment, but most people reading an instructional manual don't just read it straight through. I read from my manual for my Macintosh every once in awhile. I forget how to do something and I try go back and find it, but they never seem to have it the way I'm looking for it. There must be some special kind of strategies that are important in different kinds of occasion oriented education. This is one part of adult education that is probably different than reading a standard social science reading assignment. Sternberg is just getting started on trying to train people to be more intelligent. He hasn't really shown that he can do it yet, but I think he will. That is a good approach but there's a lot of work to do before it can be put into practice. A lot of research is needed.

Conti: A lot of the questions are coming from the practitioners. Given that, where do they start in terms of looking at the literature and doing things in the classroom that can be effective with the people they work with?

Farley: Many of the things I mentioned are probably a bit more in the future. It is going to be hard to implement many of these things. I think a computer learning environment will be helpful because computers can take into account biological changes and psychophysiological signals. I could go on all day about the technologies that are developing and, I think, that are going to change education radically. Educators are not getting ready for them. For example, a bunch of computer companies in the Silicone Valley had gotten together and were doing a thing on consciousness. They asked me to come and talk about the brain. One company had a computer with the little headband that transmitted brain waves into the computer, into their whole apparatus. You could watch your brain wave on the screen while you were doing all sorts of stuff. Now that is a strange experience! As you are learning, you see how your brain waves are changing and perhaps correlate with emotion, with reason, with problem solving, and all that sort of stuff. Some of these people have a goal in mind. They want to set up private, alternative educational systems that are computer based and are brain based, that will be an almost "1984 full-service system" in which kids or adults will be plugging their biological systems into the computer. I've been working on that idea for some time. You can plug into the machine all sorts of biological signals. The best example of telemetry that I know of is, when Armstrong stepped on the moon the Houston Space Center knew his heart rate as soon as his foot hit the dust. That was a long time ago. Telemetry has come a long way and now we can telemeter a whole host of signals off the body, out of the brain. We are now finding ways to record deep processes in the brain. These can be telemetered into receiving devices with no wire. NASA has a device, a little hat that you put on. When pilots take off in planes, they can telemeter various biological signals to tell if, at certain rates of accelera-

tion or deceleration, you get changes in the biological processes. The idea is that you want to know if someone is about to collapse and go into unconsciousness. At any rate that's off into the future, but I have absolutely no doubt whatsoever that it is coming--the putting together of brain science and cognitive science and computer science.

The immediate thing that I think will revolutionize adult education will be increasing computer mediation. Adults have access to computers now and will have increasing access. The computers are going to be much more intelligent; the programming is going to be better. Brain science has been off working away on these kinds of things and hasn't really interfaced much with educational computer science. But, it's coming.

The immediate implications are not easy to spell out. There are physiological measures that one can use in one's research. I'll just give you a flavor of one we use. My favorite used to be the salivation test, but I haven't used it for maybe five years. It actually isn't that bad, it's just a bit messy. I won't go into the boring details but it measured a salivary response. There is some evidence that salivary response is correlated with arousal in the central nervous system. What I am using these days is something that we call the sweat bottle test. The sweat bottle test is very simple to use. You are all familiar with the GSR (galvanic skin response); it goes back to the thirties. As a measure of anxiety, it has some validity. The sweating of the palm of the hand can be an indicator of an anxiety feeling or an arousal change. Robert Strahan, psychophysiologist at Iowa State University, designed a very neat little gizmo, the sweat bottle test. You take a bottle of pure distilled water and control the amount, let's say 30 cc. You put it on the palm of the hand, and let the person up end it. You hold it like that for a certain period of time, let's say five seconds, then you tip it back and stopper it. It's an interesting technique. Strahan validated it against measures of skin resistance, or polygraph measures of skin resistance.

To use the sweat bottle you put two electrodes into it and measure the resistance of the water. If the person has been anxious and perspiring, it will change the ion balance in the water which is directly correlated with change in resistance of the water. So you have a measure of systematic change. I'll give you an example of a difficult experiment to do. We did an experiment with a live theatrical production in which we were interested in arousal of the performers at different locations in the production. So we set up a laboratory behind the set, and every time someone went out on the stage, we did a sweat bottle. At the end of the production we might have had fifteen bottles for each player. I won't go into the details of this study, but in the audience we had experts and novices, to rate different qualities of performance. We then plotted the quality of performance against changes in arousal across the course of the production. That was a difficult situation to do research because these people were not in the mood. They were nervous waiting to go out there and we say, "Come on you've got to do the bottle before you go out there."

The first time I ever used it I was working with a group of prisoners and this great, big, huge murderer comes in. This is before I trained people to use this themselves, so I would be holding the person's hand. That's alright when you're working with kids, but this great big guy. . . .I said: "Now I want to hold your hand and I'm going to put this water on it with this bottle." This guy looked at me and looked at the bottle and then (this is serendipity) I suddenly thought, "I don't think I'll do it this way." I said: "Why don't you take the bottle?" So I changed the technique. But that's the sweat bottle technique.

By the way, you can use all sorts of machines to measure the resistance of the

water. Limnology Departments at universities have little machines into which you actually poor the water and then you can press the buttons and get more information out of that water than you care to know about, including the resistance of the water. Anyway that is a very usable, straight forward index of arousal.

There are hardly any adult studies done in this area at all. The power of it is that you can begin perhaps to detect biological factors in adult learners that are related to some of their learning problems or their learning successes or to individual differences.

Another avenue is to get questionnaires that have themselves been reliably correlated with physiological indexes. One that I would suggest is a test developed by Robert Thayer, The Thayer Checklist. Thayer has validated that against physiological measures. Obviously it is not as good as using the physiological measure but, sometimes you just can't use a physiological test. (Robert Thayer is in the Psychology Department at California State University, Long Beach.)

Adult educators also could look at brain hemisphere differences. There are left dominance/right dominance indicators. If ever there's virgin territory, it is biological cycles just waiting for someone in education to do research on it. The measure of biological rhythms is really very simple. I have mentioned oral thermometers, for example. Again I have to convince people that it is relevant. Everybody talks about how they're studying the mind; as soon as you start using the word brain, they think brain research is great. But when you start talking about how you are going to actually measure brain processes, they don't like it anymore. They say: "What is body temperature, sweat bottles, all these different things?" They don't see those as relevant. But when you are working at the psychophysiological level, they are relevant.

Conti: Several of the questions deal with "big T and little t." Looking at your characteristics of the "little t," I am reminded of many teachers that I've met at all levels of education. What would attract more "big T" teachers into the field?

Farley: I think you could use some kind of a system of risk and benefit. Make education entrepreneurial in some form.

Audience Member: Look at the university professor. It's not so clear that university/college professors are "little t's." In the national survey of people that are teaching in higher education, university and college faculty members tend to rank among the highest of all occupations in preference for complexity and that's one of the things that's over on your "big T" side.

Farley: I would agree with that at the college level at any rate.

Conti: Another series of questions deals with environmental factors. Are there environmental factors that you feel are particularly related to cognition and cognitive development in adult learners?

Farley: Actually, it is interesting that if you raise the heat in a room, the evidence suggests that, at a certain level of temperature, you get a drop in performance. Humidity is a big factor, by the way. It may not be so much a factor in learning but it is highly correlated with absenteeism in the work place or in schools.

McKeachie: I think one of the environmental factors, if you think about classroom learning, is the one that Barbara Grabowski has been stressing. Can I set up group learning? A lot of our classrooms are just bowls, and we can still do pairing fairly well, but are they conducive to other seating arrangements and does this affect learning?

Grabowski: There has been a lot of research on seating arrangements and area of action, but I don't recall the people who were doing that.

Farley: Round tables are definitely better than square. There's a lot on physical environment, such as the affect of fluorescent lights and humidity. The

evidence is that the humidity increases the transmission of micro-organisms from one person to another. So you have to watch it when you're in a humid room. It increases colds and it increases all sorts of things that increase absenteeism in the work place or in any environment. Another big issue these days is electrification. The fact that you're surrounded by high power lines and all that sort of stuff. What are the effects?

Grabowski: One of the things you said yesterday that was really interesting is time of day. If a person is much more effective in the afternoon than in the morning, how do you schedule your instructional activities around the time?

Farley: To know when you're most efficient would be good for the self-learner, an adult that's doing a lot of learning on one's own. It's effective time management in education.

McKeachie: I suspect all these physical things are probably less important than the psychological part of it. I'm talking about distance education and so forth. I think the evidence on Sesame Street is that it doesn't teach your kids much unless the kids talk about it with other kids, their parents or something like that. So if you're dealing with individual learners in correspondence study or distance learning, it seems to me that one of the things you've got to worry about is the kind of social supports you have for the learner. If you're doing the open university bit, how can you construct situations for people either to interact with other learners or to get their own family involved in their learning so that they don't intrude when a learner wants to be studying but instead are interested in supporting the learning?

Farley: One issue that probably doesn't receive much attention in adult education is the whole cooperative versus individualistic kind of approach. Some people have focused on public schooling, K-12, but I don't see why it couldn't be translated into the adult education realm. Might adults work better in some cooperative type learning arrangement? Johnson and Johnson did a meta-analysis of the available literature on the cooperative, competitive and individualistic learning and found that by and large cooperative learning was more effective than competitive learning or individualized learning. An article of faith in American education for some time has been that individualized learning is the ideal and if you do it you're really taking into account individual differences. Johnson and Johnson have raised a red flag on that and said maybe there's some impediment there and under certain circumstances cooperative learning is better. It's an interesting idea, and it would be important to pursue that idea in adult education and see to what extent a cooperative learning model is more effective than other types.

Conti: Several questions have been raised about metacognition. Is it a separate field from cognition or not? Just how does it fit in?

McKeachie: Metacognition, to me, is simply thinking about thinking. Thus, it is a subcategory of cognition. The degree that you are able to think about your own learning and decision making, that is metacognition. It is closely related to a concept called executive processes which involves planning your activities, choosing a strategy, deciding to do one thing rather than another.

Conti: A final question. In discussions such as this, the topic of the self-concept comes up quite often. It has been mentioned by all of you. Are there some specific ways of relating adult's self-concept to cognitive research?

McKeachie: We have a questionnaire we use called Motivated Strategies for learning. We try to get at how much learners are intrinsically oriented, how relevant is this course to their particular goals, what is their expectancy of success and other such topics relating to self efficacy. It is cognitive in the sense that the

self is a cognition, just like any other concept. To study what changes cognitions about one's self is something like studying how we change concepts like mass energy, or other things. The problem is that the self is a concept with a high value attached so a lot of emotion enters in here.

Farley: An important aspect of the whole topic is the sense of competence. If people have a sense of competence they are going to have a sense of self-confidence. One of the factors in developing a sense of competency is the linkage between effort and outcome. If what you do has an impact, then you're going to have a sense of self-confidence. But if what you do doesn't seem to have any impact on anything, if it doesn't help you move ahead with what you want to do, then you are not going to develop much of a sense of competence and you will have a lousy sense of self-confidence. So I think the crucial thing is the linkage between effort and outcome. If you put effort into something, you have to believe it will have an impact. You have to work with people who have a self-esteem problem to show them that what they do does make a difference. One of the crucial things is the steps between; that is, you want to show them that it often takes a number of steps to get to an outcome. A number of steps are often necessary and must be worked through to get to a desired outcome. This can help individuals develop a sense of competence and lead to a positive self-image.

An important aspect of this is risk taking. As I talked about yesterday, a healthy sense of risk taking is important. If you are going to grow as a person, you are going to have to take risks. If you want to be a stagnant person, you can sit around avoiding risks. I define risk as engaging in something with an uncertain outcome. Education needs to promote creative risk taking in order to help people grow.